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NUCLEAR ENERGY ENGINEER

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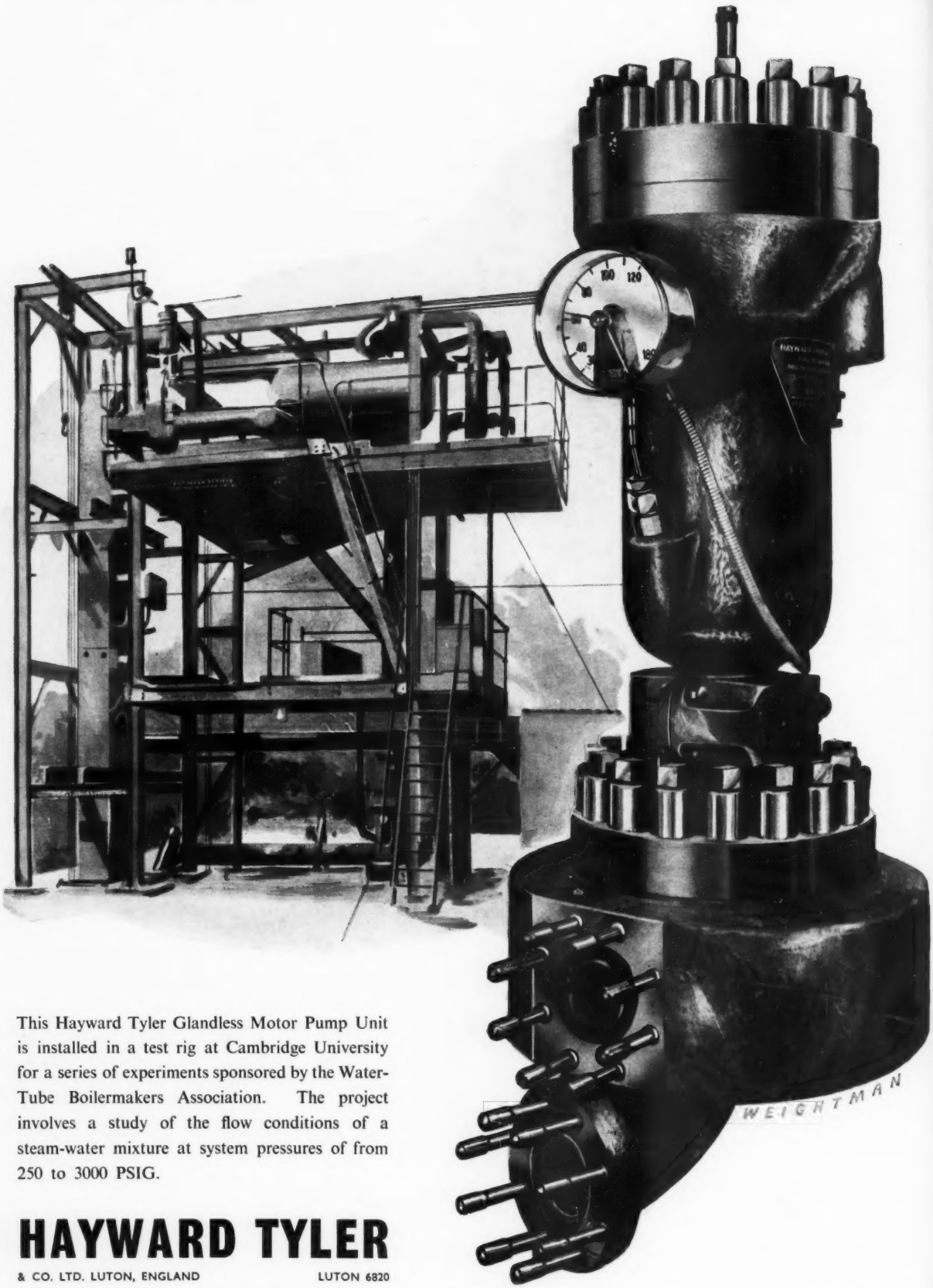
Whatever the weather, work at Berkeley goes on. Most of the civil engineering work has been completed and John Thompson's report that number one reactor vessel has been welded and that number two is well under way. Equipment from the Heavy Plant and Turbine Generator Division of AEI is now being installed.

A·E·I
JOHN THOMPSON



This Hayward Tyler Glandless Motor Pump Unit is installed in a test rig at Cambridge University for a series of experiments sponsored by the Water-Tube Boilermakers Association. The project involves a study of the flow conditions of a steam-water mixture at system pressures of from 250 to 3000 PSIG.

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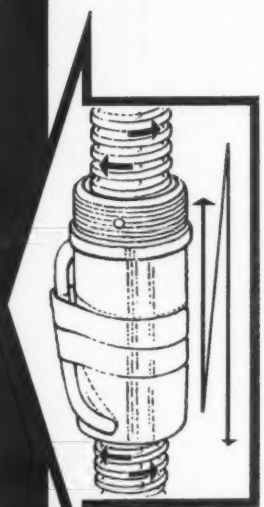

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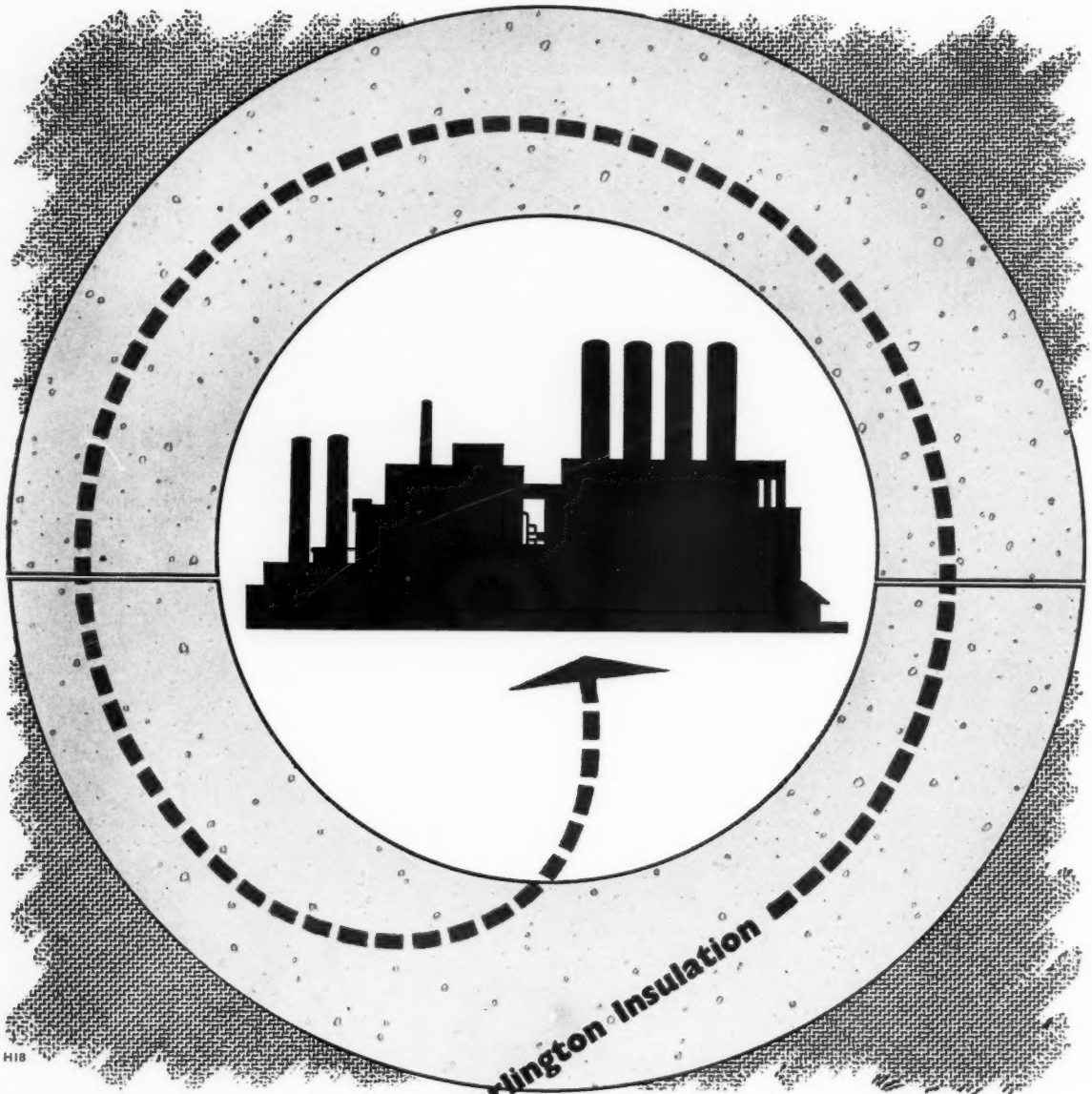

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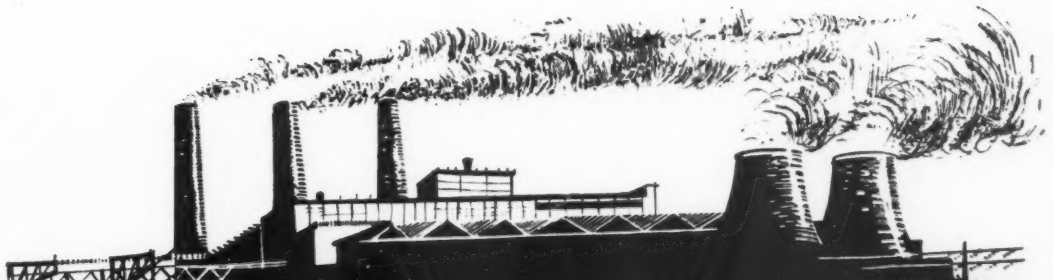

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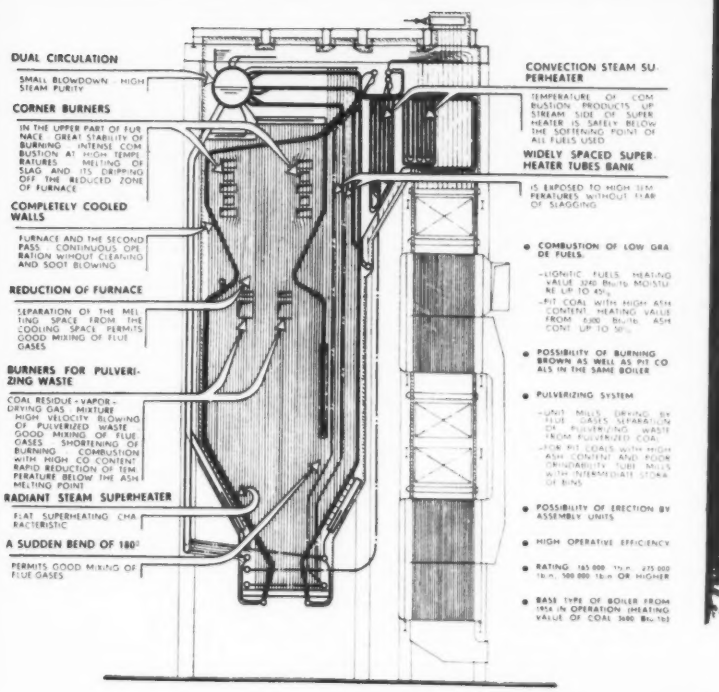
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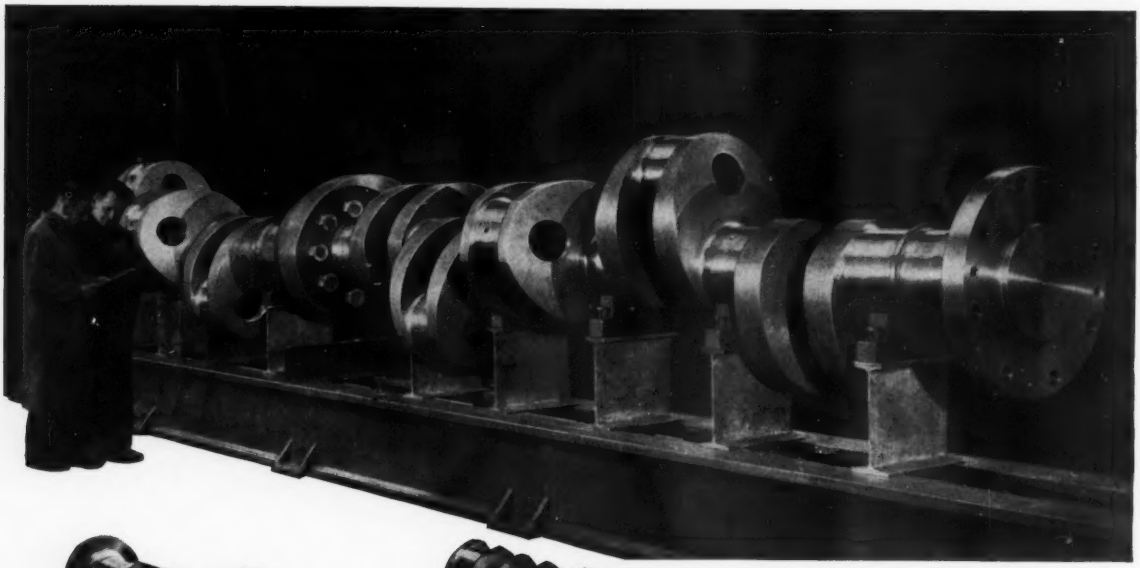

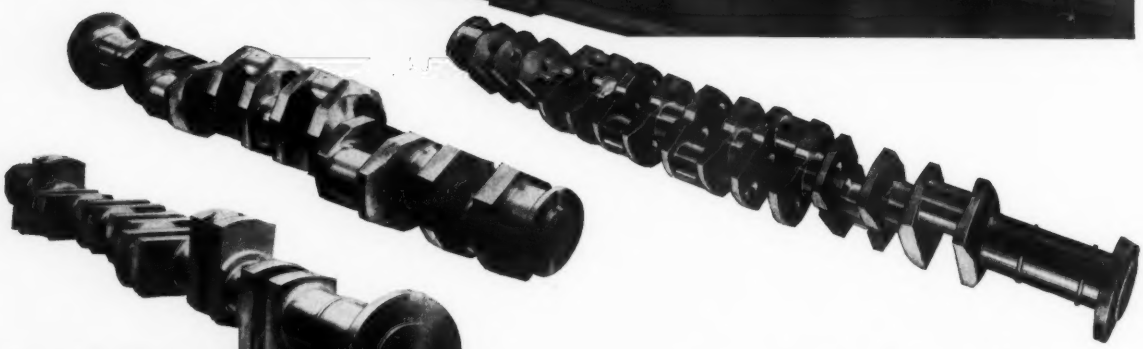

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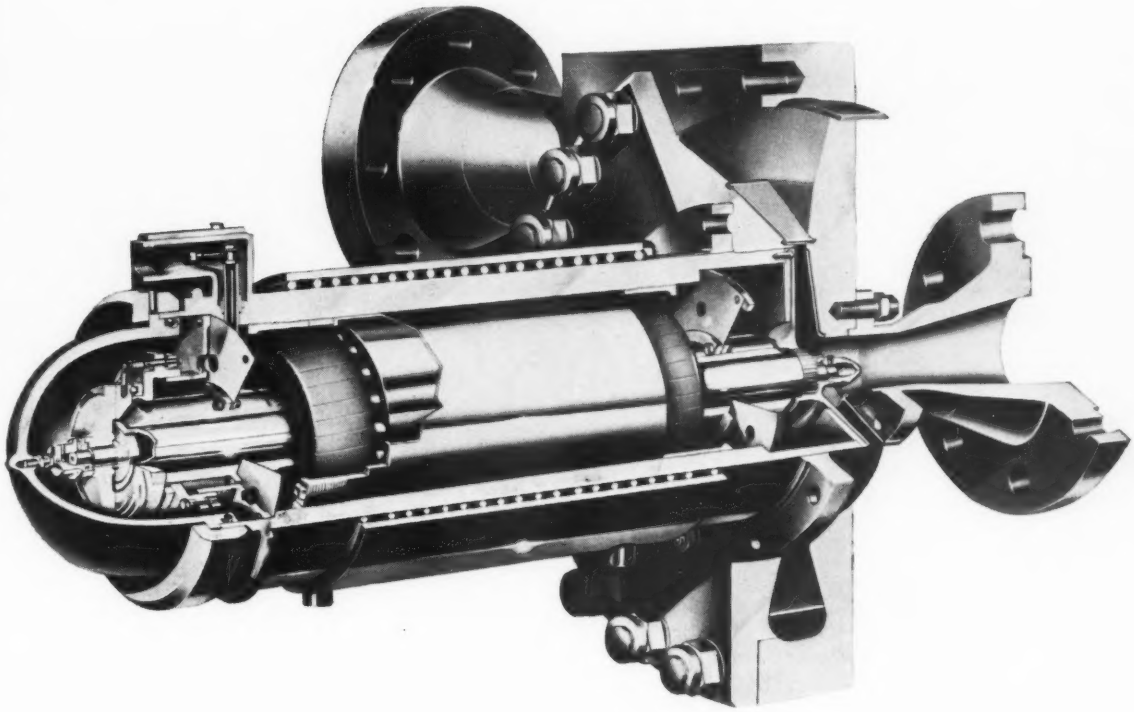

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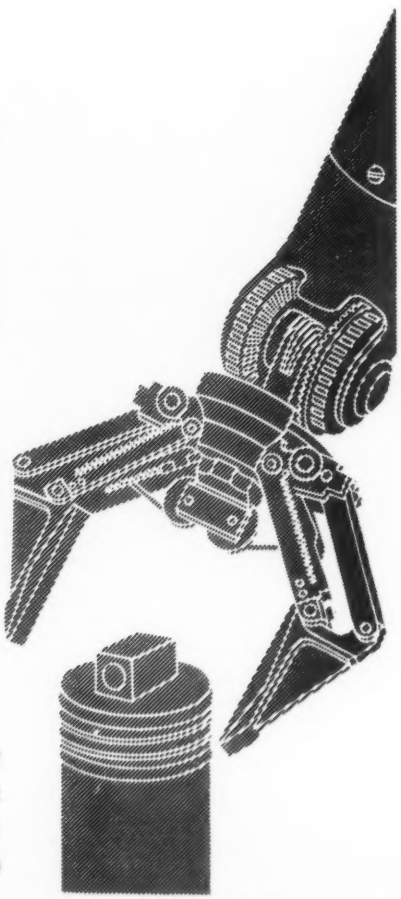

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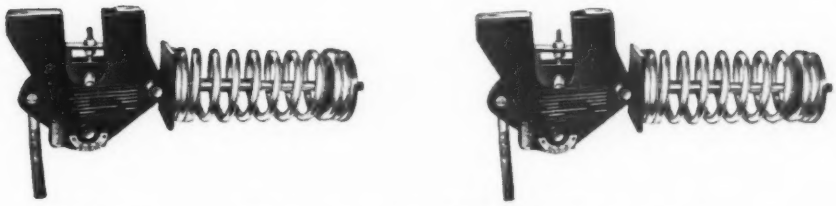

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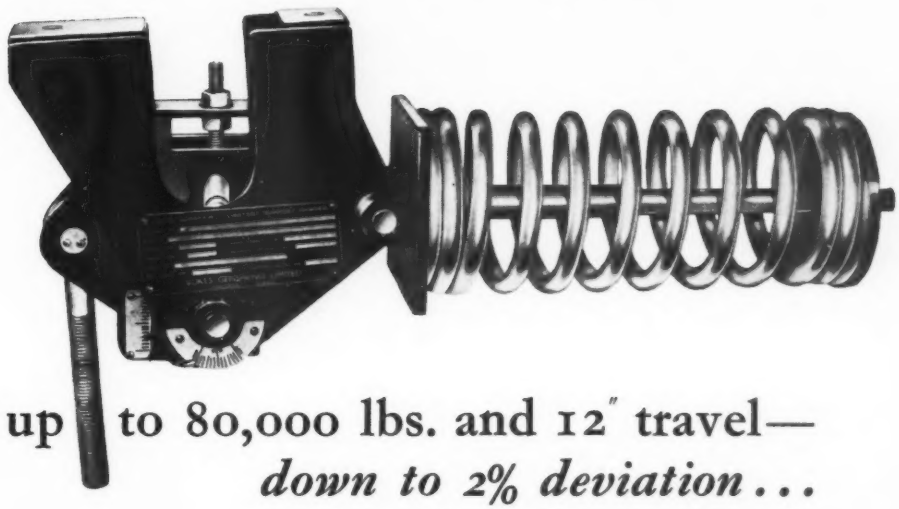

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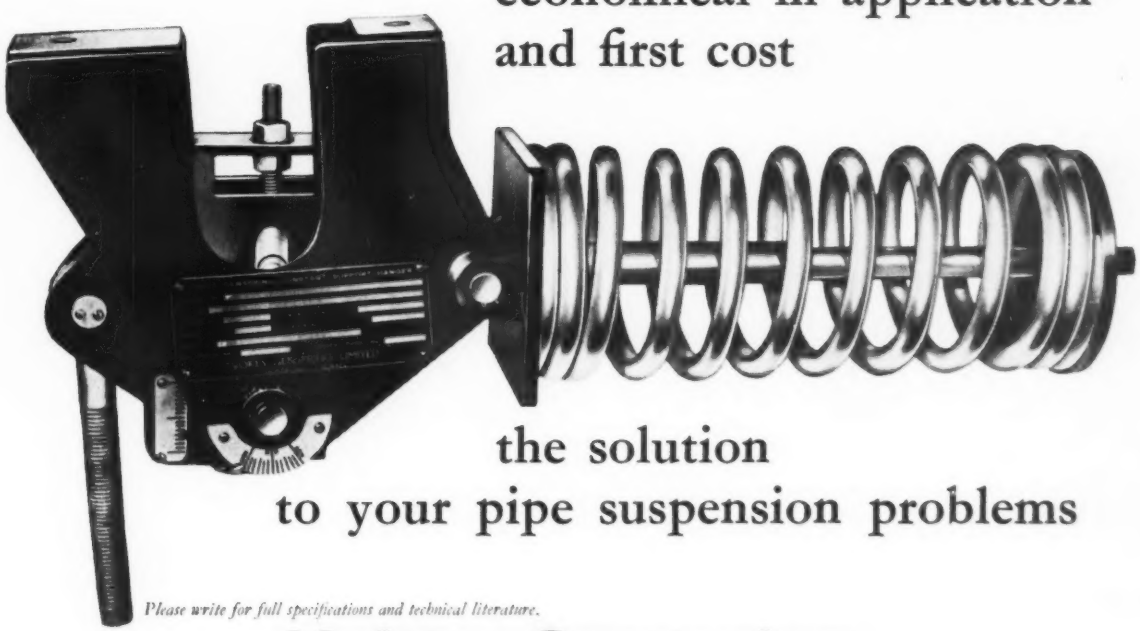

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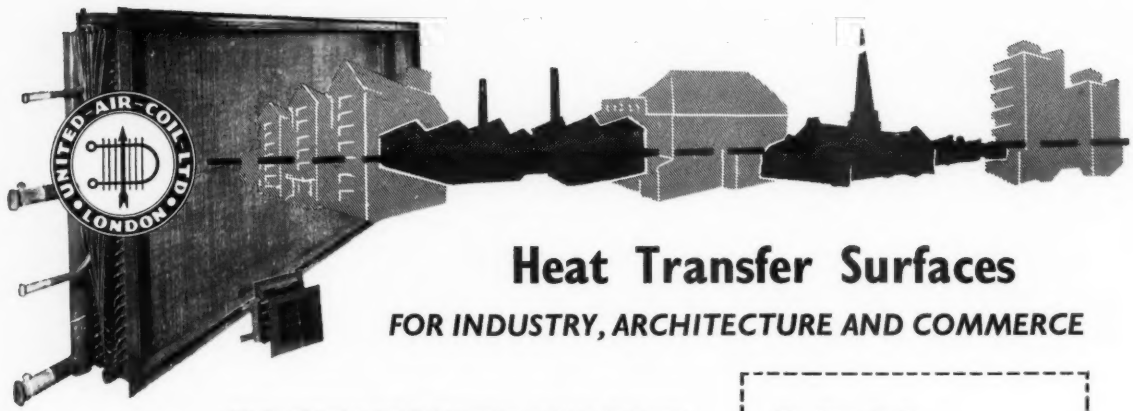

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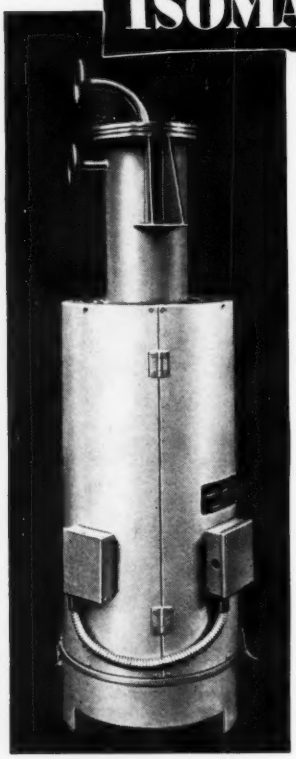

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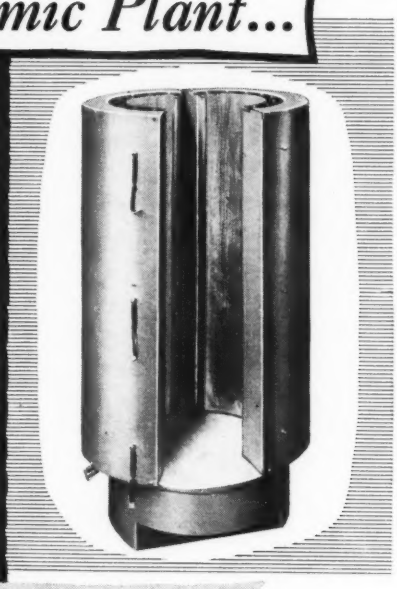

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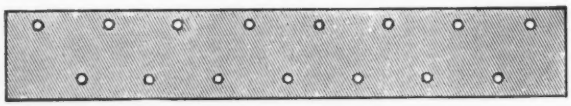

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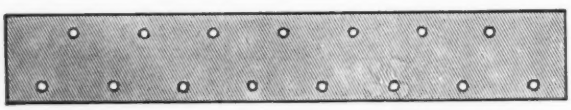

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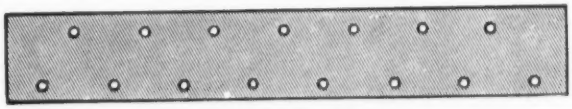

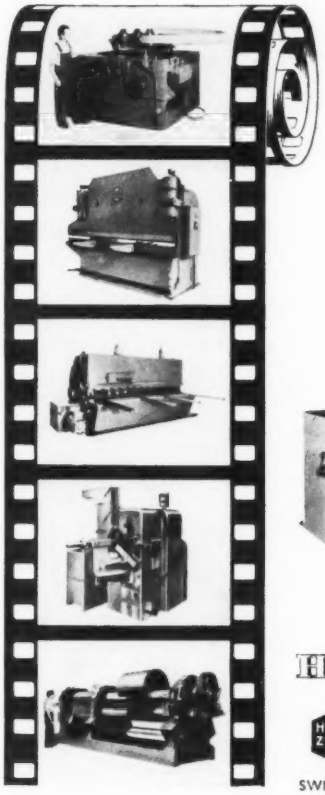

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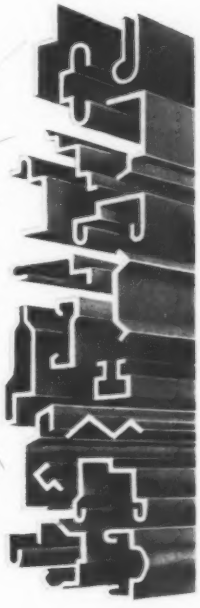

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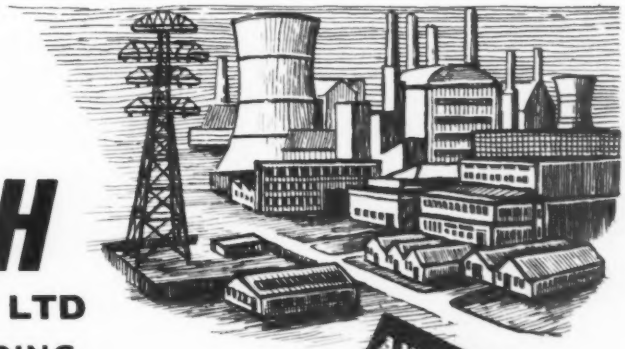

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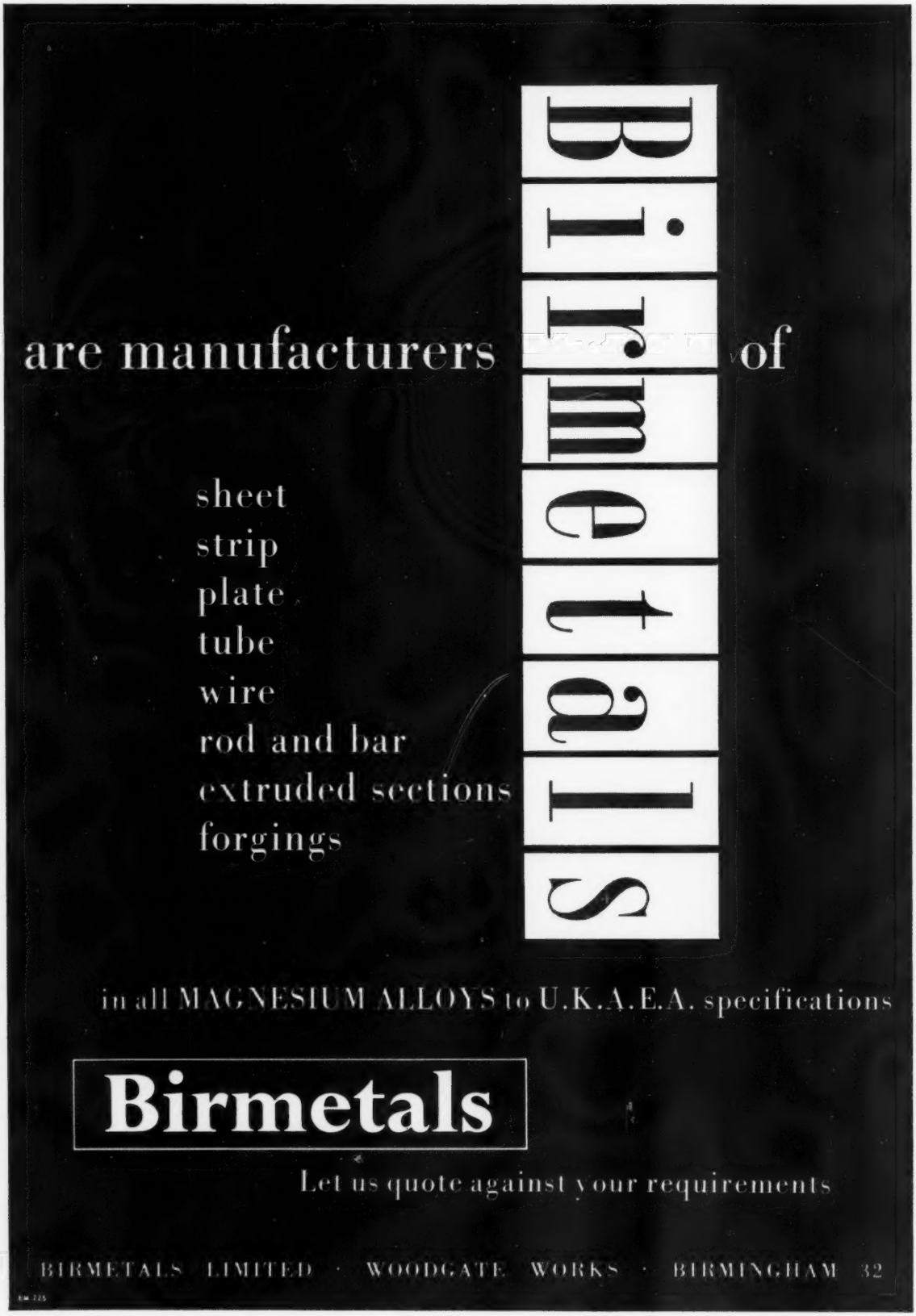
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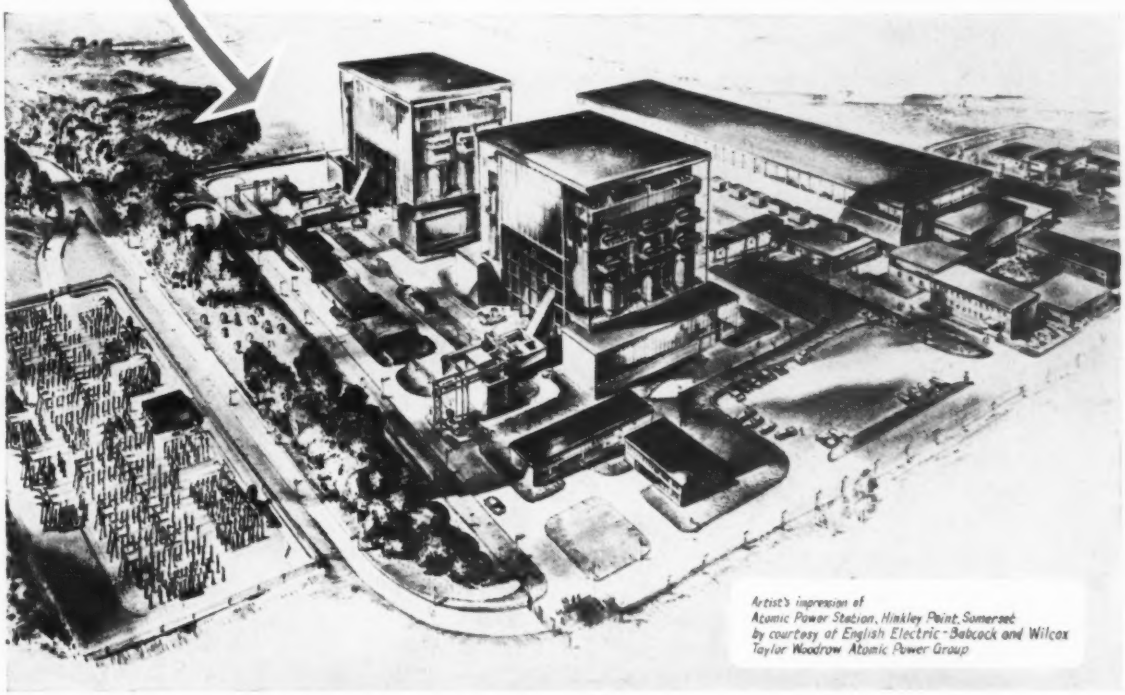

Artist's impression of Atomic Power Station, Hinkley Point, Somerset, by courtesy of English Electric-Babcock and Wilcox Taylor Woodrow Atomic Power Group

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NUCLEAR ENERGY ENGINEER

Vol. 13 No. 131

APRIL, 1959

CONTENTS

PAGE

HERO—Preliminary to the AGR 189

Fuel Elements for Dounreay Fast Reactor, by D. S. Oliver, BSc, PhD 190

Japan's First N-Power Station 194

NUCLEAR ENERGY ENGINEER'S *First Anniversary* 195

Isotopes Assist Sewage Engineers 196

Nuclear Developments in America, by J. Burkett 199

Nuclearist Writes 204

Quarter of the Way There 205

Radiation Balance Calorimeter 206

Structure of Matter in " Glassy " State .. 207

People in the Nuclear News 209

Nuclear News 210

Preparing a Tender, by David Welsh 213

Building the Reactor, by A. L. Brake AMIStructE 215

DRAGON—International Reactor Project .. 219

Engineering, Marine, Welding and Nuclear Energy Exhibition—A Preview 222

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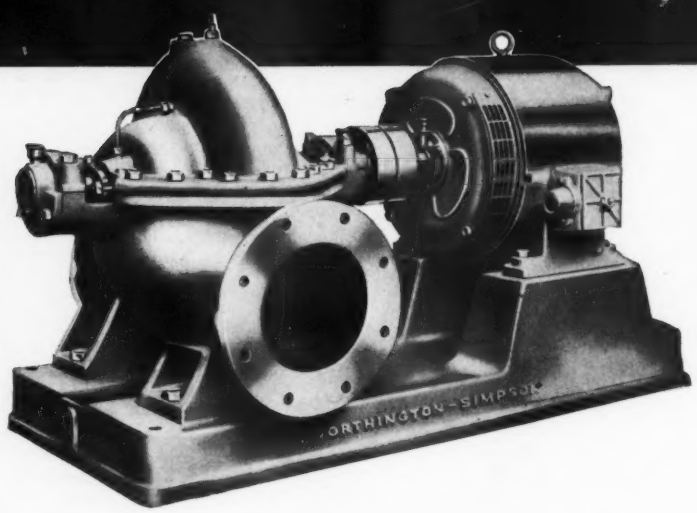

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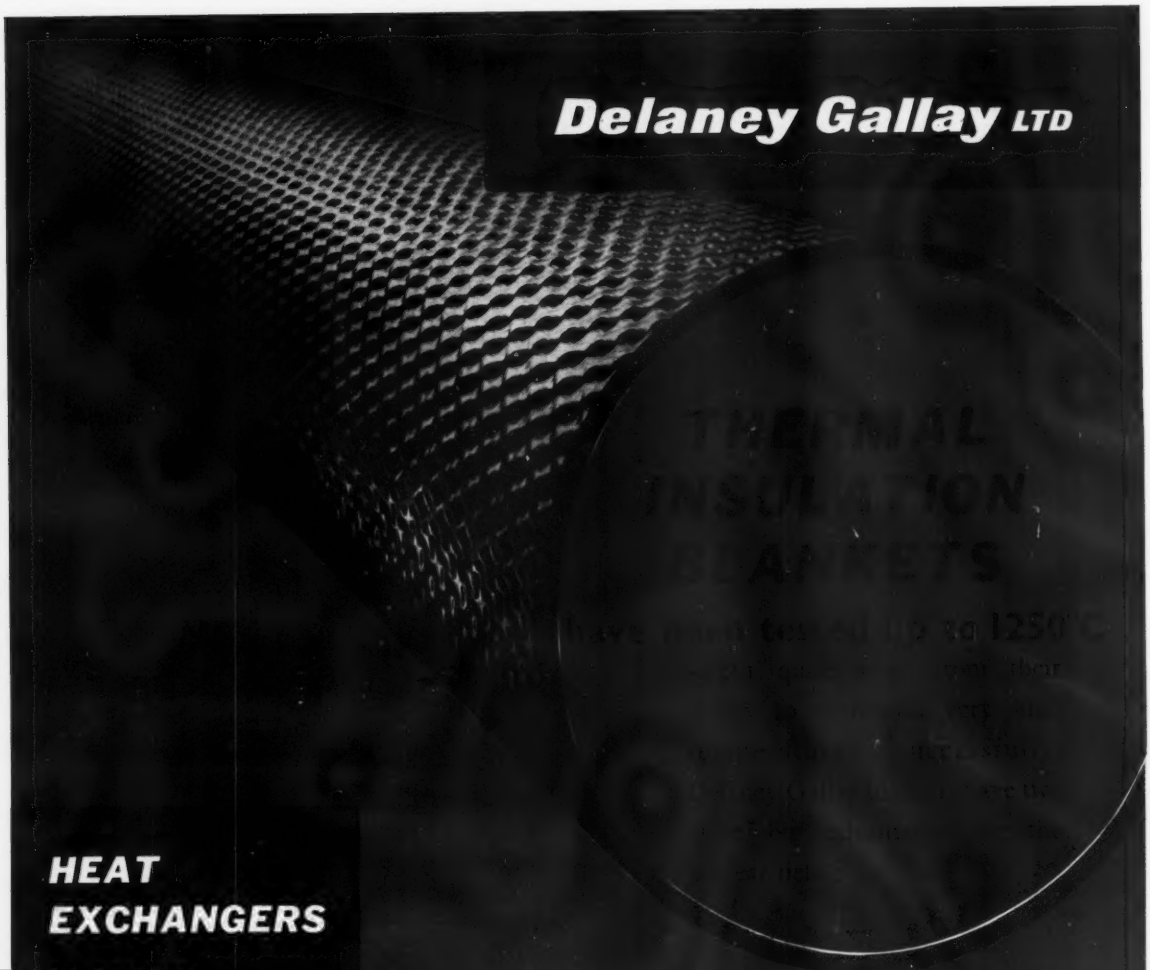

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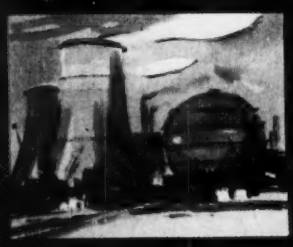

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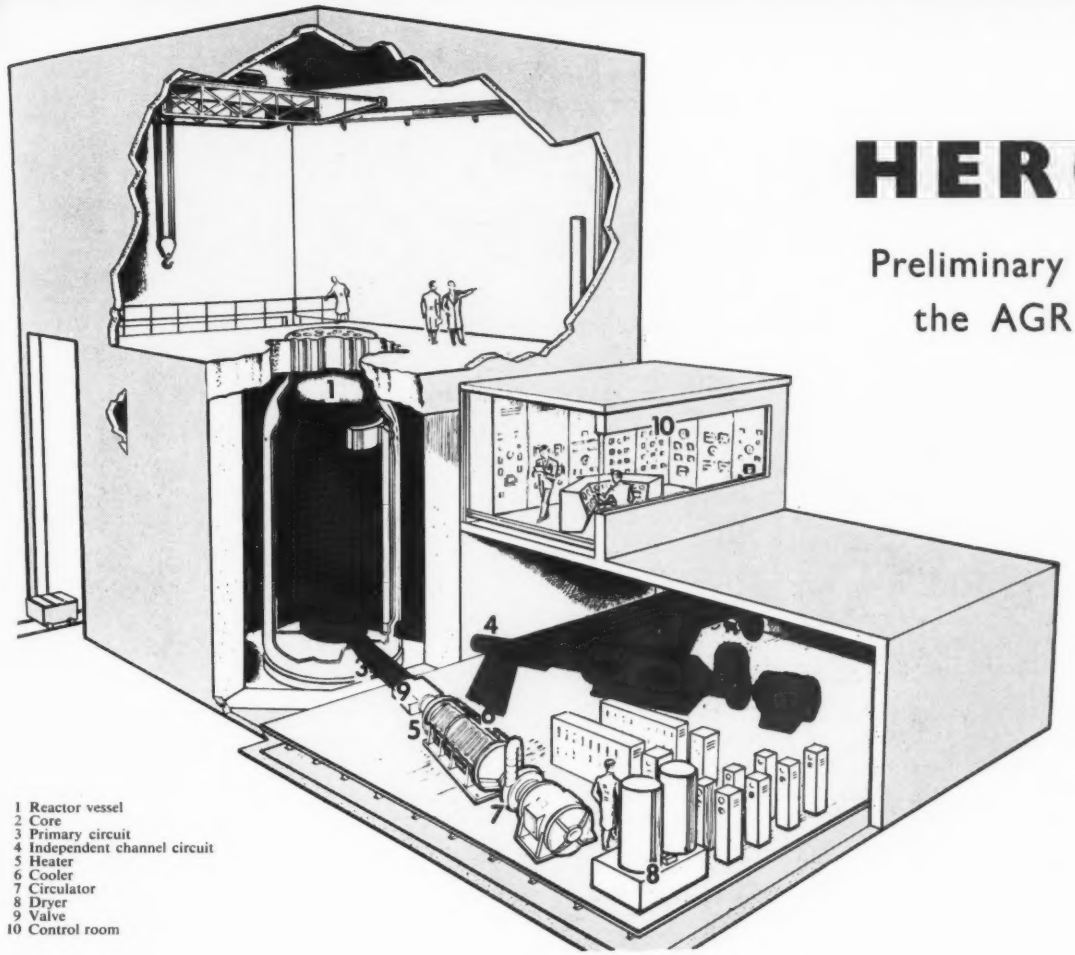
HERO

Preliminary to the AGR



1 Reactor vessel
2 Core
3 Primary circuit
4 Independent channel circuit
5 Heater
6 Cooler
7 Circulator
8 Dryer
9 Valve
10 Control room

A NEW low-power research reactor is to be built at Windscale, which is being expanded as one of the national centres for the development of gas cooled reactors.

The new reactor will be known as HERO, a name derived from its description as a Hot Experimental Reactor of 0 (zero) power. It will cost about £1½m. and will be built near the Advanced Gas Cooled Reactor (AGR) on which work has already started. Its function will be to complement the work of AGR by making it possible to carry out low radiation level measurements and to experiment with several alternative arrangements of fuel to obtain the best results.

It will be completed early in 1961 and will be operated and studied by physicists of the Research and Development Branch and the Windscale laboratories.

HERO, which will generate a few kW of heat, will consist initially of a graphite structure 19 ft in diameter and 19 ft high but an important feature is that it will be possible to dismantle it and rebuild it in a variety of ways. The graphite core will be contained in a steel vessel connected to a pipe circuit with pumps and heaters so that it can be operated at high temperature in carbon dioxide. It will, in fact, be the reverse of the AGR since the carbon dioxide gas will supply heat to the core instead of removing heat from it. The fuel will consist as in AGR of clusters of pencil-like rods of uranium oxide sealed into beryllium cans, and these will be arranged in channels in the graphite on a regular lattice.

It is expected that from about 1965 onwards the reactors for nuclear power stations will be based on AGR, using uranium oxide fuel and beryllium instead of magnesium cans. This will permit higher operating temperatures and heat ratings and consequently will lead to greater efficiencies than can be achieved in the reactors currently being built for the Electricity Authorities. The levels of radiation inside the reactors will be considerably higher. Two broad categories of problems are raised by these more arduous conditions: those of reactor physics and those of reactor materials.

The most important material problem is to develop fuel elements which can withstand high burn-up under the exacting conditions of high temperature and high flux and the main purpose of the AGR prototype is to test various types of fuel under full reactor conditions—it is essentially a fuel element development reactor. For this reason it has been designed to operate at 100,000 kW of heat, generating 30,000 kW of electricity, and it will be most important for it to run at high power for prolonged periods.

The reactor physics problems concern the behaviour of neutrons within the reactor. The high radiation levels necessary in AGR for fuel testing and power production prevent the physicist from gaining access to the parts of the reactor which need most careful study. Sensitive techniques, however, are available with which it will be possible to carry out the necessary measurements at low radiation levels in HERO. The importance of highly refined reactor physics work lies in the very competitive nature of present-day reactor design, which demands extremely careful optimization of reactor cores. With the large programme of nuclear power installation in the United Kingdom, even a slight improvement in efficiency brings appreciable returns.

FUEL ELEMENTS for the DOUNREAY FAST REACTOR

THEIR DESIGN AND MANUFACTURE

by D. S. OLIVER, B.Sc., Ph.D.

Research Manager, U.K.A.E.A., Dounreay

The Dounreay Fast Reactor has been designed and constructed to demonstrate the feasibility of highly rated liquid metal cooled reactors, and to provide the necessary information and experience to support the design of a prototype industrial fast reactor burning a plutonium fuel. The success of the reactor will depend to a large extent on the satisfactory performance of the fuel elements. This article describes the conditions under which the elements will operate and the way in which the element has been designed to withstand these conditions, together with a description of the manner in which the fuel elements are manufactured.

THE core of the Dounreay Fast Reactor, which approximates to a 2 ft diameter upright cylinder and which is made up from over 300 separate fuel elements, has a designed maximum heat output of 60 MW. This heat is transferred from the core to the primary heat exchangers by the primary coolant of sodium or sodium-potassium alloy, which enters the top of the core at a temperature of 200°C. and leaves the bottom of the core at an average temperature of 400°C.

Damage Very Likely

The neutron flux will have a maximum value of approximately 10^{15} neutrons/cm²/sec at the centre of the core, whilst the outermost fuel elements will receive about one-third of the flux to which the centre fuel element is subjected. The heat output varies directly with neutron flux so that, since the coolant flow rate is the same for each fuel element, the temperatures in the fuel elements will decrease from the centre to the outside of the core. It has been calculated that at 60 MW the maximum fuel temperature in the centre fuel element will be 800°C., and this will be associated with radial temperature gradients in the fuel of approximately 1,000°C./in. Furthermore, these temperatures and temperature gradients will fluctuate during reactor operation, as, for example, each time the reactor is started up or shut down, and such temperature cycling can produce damage in uranium fuels, particularly if the cycle includes the alpha-beta transformation temperature[1].

In addition to these severe temperature conditions, the fuel elements will have to withstand the effects of the fission process itself, which can produce damage of two kinds[2,3]. At temperatures in the region of 200°C. and with an anisotropic material such as uranium, the very localized release of heat associated with each fission causes the crystal in which it occurs to elongate in one crystallographic direction by a very small amount. After the very large number of fissions to which a fuel element is subjected during its life in the reactor these small elongations lead to overall deformation of the fuel. In the case of fuel having a strongly developed preferred orientation, such as may result from some mechanical working processes, the damage is manifested by a change in dimensions without change in volume of the fuel piece; if on the other hand the fuel has a random texture, such as may be produced by casting, the damage will show as a rumpling of the fuel surface.

Poisoning Trouble

At higher temperatures, in excess of 500°C., this type of damage disappears and a second mechanism starts to operate. In this case it is the rare gas fission products krypton and xenon, which amount to approximately 10 per cent. of the total fission product yield, which cause trouble. At these higher temperatures the rare gas atoms have sufficient mobility in the fuel lattice to diffuse to existing voids in the metal or to collect together to form new voids, where they exert such a pressure on the fuel that it swells. Since the temperatures in the Dounreay Fast Reactor range from 200°C. to 800°C., both types of damage are possible and must be guarded against.

Thus some of the factors which influenced the design of the fuel element and the selection of materials for its manufacture were the high power density with its associated high temperatures and steep temperature gradients, both of which will fluctuate, the use of sodium and sodium-potassium alloy coolants with their particular corrosion problems, and the occurrence of two different types of irradiation damage. To these must be added the criterion that, in the event of a power excursion in the reactor leading to melting of the fuel, the fuel element must fail in such a manner that the reactor becomes sub-critical.

Although the fissile material most suited for burning in a fast reactor is plutonium, the initial charges for the Dounreay reactor will be made from

THE AUTHOR

Dr. D. S. Oliver, who is research manager in charge of fuel element research, development and production at the Dounreay Experimental Reactor Establishment, was born in 1926 and graduated in physical and theoretical metallurgy at Birmingham University. He then carried out research on recrystallization of copper for his PhD degree. A period of work at the H. H. Wills Physical Laboratory at Bristol University followed and in 1952 he joined the research and development branch of the UKAEA at Culceth. Two years later he went to Dounreay.

highly enriched uranium. A plutonium core will be introduced into the reactor when supplies of this metal are available in quantity and when the technology of its fabrication has been suitably developed. The requirement was thus specified as a uranium base fuel which could be fabricated to the required shape and which would have a good resistance to both irradiation damage and thermal cycling damage.

Fine Grained Alloys

It is known that the effects of the lower temperature type of irradiation damage can be minimized by the use of a randomly oriented, fine grained material so that, to meet the specification, development was concentrated on uranium alloys capable of production in such a condition. These were subjected to extensive fabrication trials and thermal cycling tests and uranium alloyed with $\frac{1}{2}$ atomic per cent. (1,200 p.p.m. by weight) of chromium was selected. This material has excellent resistance to thermal cycling damage and can be reproducibly produced with a grain size of less than 0.1 mm following heat treatment.

In order to reduce the effects of irradiation swelling it was decided to use a strong can for the element, thus constraining the fuel, and to vent the can to permit the escape of any gaseous fission products liberated from the fuel.

The high power density in the reactor necessitates the use of a fairly thin fuel section with a large surface to volume ratio. From the various shapes which satisfy this condition an annular design was selected since, as is described below, this provides a suitable form into which a safety device may be incorporated.

The various problems involved in the selection of canning materials which are compatible with sodium, sodium-potassium alloys and uranium have been reviewed by McIntosh and Bagley[4]. These studies lead to the short listing of tungsten, molybdenum, titanium, zirconium, hafnium, rhenium, tantalum, niobium and vanadium as potential can materials. Of these, hafnium and rhenium are not available in large enough quantities, tungsten and molybdenum present major fabrication problems, titanium and zirconium have poor thermal conductivities and creep strengths, whilst tantalum has a relatively large capture cross section for fast neutrons. Two materials, niobium and vanadium, were selected rather than one because of the need for a melt-out safety device (see below). Neither of these materials was available in a suitable form, and the development work undertaken to produce suitable metal has been described by Turner and Williams[5].

In the event of overheating and melting of the fuel, such as could possibly arise from a power surge in the reactor or because of loss of coolant, it is essential that the fuel runs out of the fuel elements in such a manner that it leads to the reactor becoming sub-critical. With the annular design of fuel element this has been achieved by selecting two different materials for the outer and inner tubes (niobium and vanadium respectively) such that the inner tubes are penetrated by molten uranium at a lower temperature than the outer tubes. The liquid fuel is thus directed down the inner tubes, through the bottom core support plate, into a vessel of such a shape that a critical assembly cannot be formed and the reactor becomes sub-critical[6].

Accurate Loading

So that the elements can be loaded into and positioned accurately within the core, stainless steel fittings are attached at either end of the element. The one at the top is designed to attach to the reactor charging machine, whilst that at the bottom locates the element in the core base plate.

A further requirement for the outer niobium tube is that it should have sections of external, helical fins along its length so that, should two adjacent elements bow and touch, local overheating cannot occur.

The vanadium inner tube is not rigidly attached to the rest of the assembly, being a sliding fit in the top and bottom plugs, so that there is no risk of differential thermal expansion of the outer and inner tube imposing a stress on the element. This lack of a seal at these points is immaterial since the fuel element is filled with sodium to transfer the heat from the fuel to the can and, in any case, the can is vented.

The final fuel element design is shown in Fig. 1.

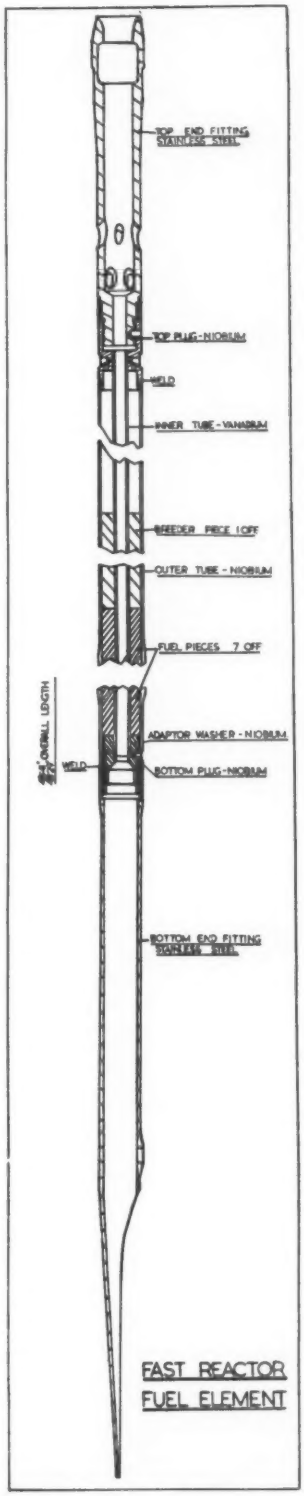


Fig. 1.—Final design of fuel element for the Dounreay breeder reactor

Before discussing the manufacturing techniques employed in the production of the fuel elements, some of the general problems arising in plants manufacturing components in concentrated fissile materials such as highly enriched uranium or plutonium must be described.

Criticality Control

One of the major problems in such plants is that of criticality control, that is preventing the accumulation in any one part of the plant of sufficient fissile material to form a critical assembly. To accomplish this control the plant is divided into a number of units, each representing one part of the process, and these units are separated physically from each other in separate rooms, cubicles or glove boxes. Each part of the process is then carefully examined and a quantity of material is assessed which cannot possibly become critical during this operation; this is the criticality limit for the particular plant, process or operation. All movements of fissile material from one part of the process to another are controlled by a single member of the staff, who ensures that the criticality limits are never exceeded and that the actual physical movements are carried out in a safe manner.

As a further safeguard against human fallibility, double locks are installed at various strategic points of the plant, so that major redispositions of the fissile material in the building cannot be made without the active participation of the fissile material controller and one other responsible member of the staff. All of these movements are recorded, and a fissile material balance for the whole of the plant is carried out at frequent intervals, during which all of the materials accounts are carefully checked to ensure no discrepancies and that no material accumulates in any part of the plant. It will be appreciated that this problem, which is peculiar to the nuclear energy industry, is highly complex, particularly in such operations as machining, and requires a very high standard of managerial control.

Pollution Problem

The second major problem is the prevention of the ingestion or inhalation of uranium and plutonium, the latter in particular being a highly toxic material. To protect the operators from these health hazards all of the operations are carried out in glove boxes, that is metal boxes having viewing windows and integrally attached rubber gloves through which the operations are performed. The operator is thus separated from the material by a complete physical barrier. A second line of defence is also provided by placing the glove boxes in highly ventilated cubicles in which air is continually drawn away from the workers. A cross-section of typical glove box is given in Fig. 2.

Efficiency Essential

To these two requirements must be added the fact that fissile material is extremely valuable. Thus fissile material accounting is essential for financial as well as criticality control, and the processes must operate with the greatest possible overall efficiency.

The charge for the melting and casting of the fuel is made up of enriched uranium, and a button of uranium-chromium master alloy previously made by arc melting a compact of chromium and uranium swarf from the machining operation. The charge is contained in a graphite crucible which is suitably lagged and contained in a continuously evacuated vitreosil chamber. Heating is carried out by an external inductor coil. The uranium alloy is cast into graphite moulds, containing graphite cores to give the annular section, by a mechanism operated from outside the chamber which lifts a stopper plate covering a hole in the base of the crucible. The equipment is shown schematically in Fig. 3.

After casting, the graphite cores are drilled from the uranium alloy tubes, the headers are removed and recycled through the casting process, and the tubes are heat treated to produce a fine grain size. This heat treatment is carried out by soaking the pieces in a salt bath maintained at 730°C. (i.e., in the β phase region) and then transferring the tubes to a second salt bath at 530°C., which is within the α phase region. The resulting isothermal phase transformation yields the required fine grain size.

The tubes are then machined to length and the outer diameter turned to size. These machining operations are performed dry in a glove box having an argon atmosphere. The swarf is thus kept free of oxide and can be arc-melted and recycled to the casting process. One of the lathes and lathe boxes used for this machining is shown in Fig. 4.

Argon Welding

The tubes are next electropolished, to provide a surface easily wetted by sodium, and all of the components are assembled together. During this assembly operation the niobium tube is welded to the top and bottom niobium plugs and, because of the very rapid reaction between hot niobium and oxygen or nitrogen, these welds are made in a container which is evacuated and filled with purified argon prior to each welding operation. The final processing operation is to fill the element with sodium, which is done by heating the element to 550°C. and passing liquid sodium into the bottom of the

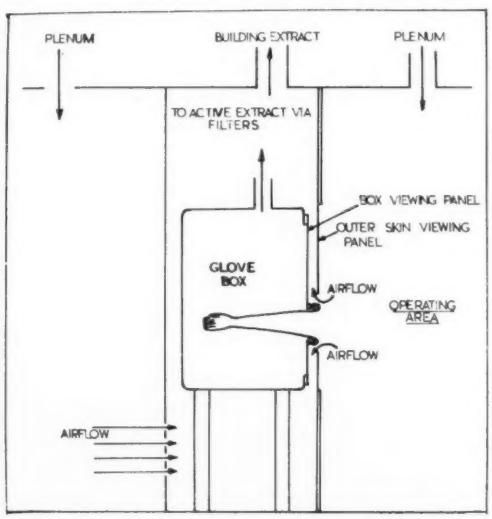


Fig. 2.—Cross section of typical glove box showing additional protection given by ventilation

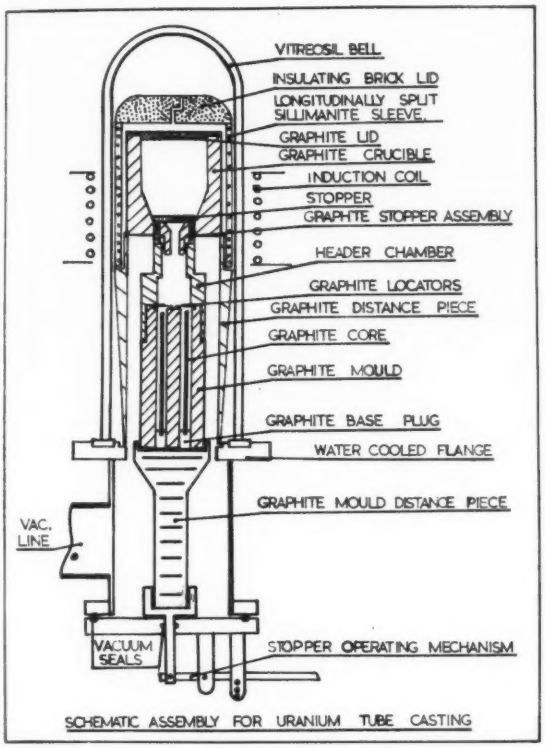


Fig. 3.—Fuel tube casting

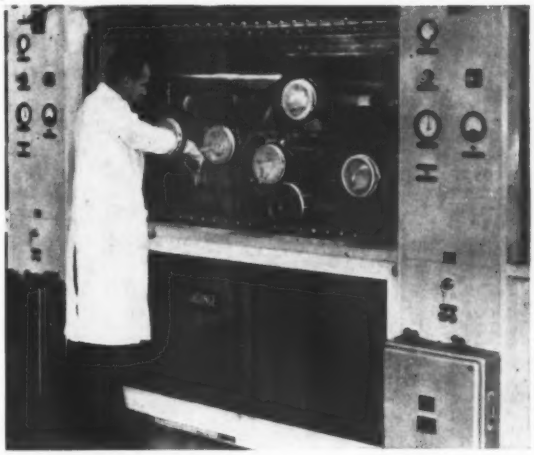


Fig. 4.—Lathe glove box

element until it overflows through the vent hole at the top.

At all stages throughout the process inspection is carried out to ensure that the components are dimensionally accurate and of the required quality. After the final inspection the elements are put into wooden containers and shipped to the reactor.

Other Materials Tested

The fuel element which has just been described is considered to be only a starting point in the development of fast reactor fuel elements. Other shapes have their peculiar advantages both in the reactor and during processing, other fuel alloys may have superior resistance to irradiation damage, and, above all, plutonium will be used eventually instead of uranium.

In order to achieve the best possible fuel element, a development laboratory which is equipped to carry out metallurgical fabrication of all types has been constructed in addition to the production building. During the first few years of operation of the Dounreay Fast Reactor, many different types of fuel element, some containing uranium and some plutonium, will be manufactured in the development laboratory for testing in the reactor. As the results of post-irradiation examination are obtained and considered with the information on manufacturing characteristics, so improved fuel elements will be put into production. Even when the prototype industrial fast reactor is in operation this work will still continue so that the maximum overall efficiency is achieved with this most promising type of nuclear power plant.

The design and development work described have been carried out in many different sections of the Industrial Group, and acknowledgement is made to colleagues whose work has been included. Thanks are also due to Sir Leonard Owen, CBE, managing director, and Dr. R. Hurst, GM, JP, Director of DERE, of the United Kingdom Atomic Energy Authority (Industrial Group) for permission to present this article.

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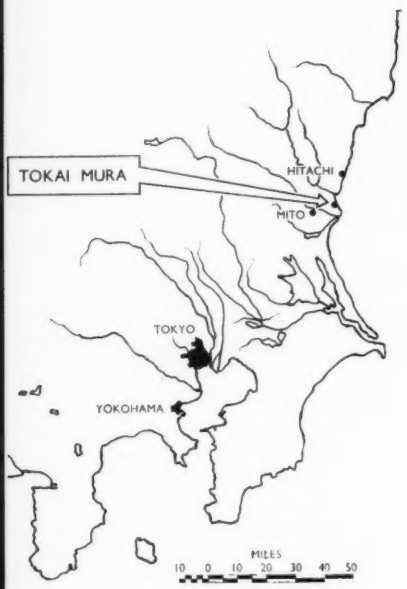
Book Review

Nuclear Engineering Handbook. Edited by Harold Etherington. Size 9¼ in. × 6 in. × 1,872 pp. Price 194s. Published by McGraw Hill Publishing Co., Ltd.

All aspects of nuclear technology are covered in this book, which range from fundamental nuclear theory to reactor design and the economics of nuclear power. Over 70 experts have contributed. The text is divided into 14 sections—mathematical data and general tables, nuclear data, mathematics, nuclear physics, experimental techniques, reactor physics, radiation and radiological protection, control of reactors, fluid and heat flow, reactor materials, chemistry and chemical engineering, nuclear power plant selection, mechanical design and operation of reactors and isotopes. The sections are numbered so as to make cross references easy. There is also a comprehensive index. There is little in the book about such subjects as thermonuclear apparatus and the nuclear propulsion of ships and aircraft, a trifle disappointing considering that the editor was at one time director of the naval research at Argonne. It is essentially a practical fission book and for the engineer or any other person interested in industrial and other applications of nuclear energy is indispensable. The contributors, incidentally, with one exception, are scientists and engineers working in industry, universities or the U.S. Atomic Energy Commission. The exception is Elesa R. Etherington, BSc, who helped the editor, her husband presumably, with the compilation of the section on mathematical data. She is described as a housewife—a refreshingly unusual occupation to find mentioned in a book that is otherwise a welter of technical information.



JAPAN'S FIRST N-POWER STATION

NEGOTIATIONS WITH G.E.C.

JAPAN'S first nuclear power station, to be sited at Tokai Murai, 65 miles north-east of Tokyo, is likely to be a smaller, modified version of the type being built by the General Electric Co., Ltd., and Simon-Carves Ltd., at Hunterston, Ayrshire. GEC's design, in competition with designs from other British nuclear power consortia, has been approved by the Japan Atomic Energy Co., and a letter of intent to enter into contract is expected very shortly. Value of the contract, details of which should be completed by the end of this year, will be about £30m.

Although the GEC, if they are awarded the contract, will be responsible for the design of the entire project, certain parts will be manufactured and most of the construction work undertaken by Japanese firms. To this purpose 14 leading Japanese companies have formed a consortium, the First Atomic Power Industrial Group (FAGIP), with whom GEC recently concluded a long-term licensing agreement.

It is thought that about a half, or even less, of the station will be manufactured in Britain. It is very likely that even the pressure vessels and boilers will be manufactured by Japanese industry.

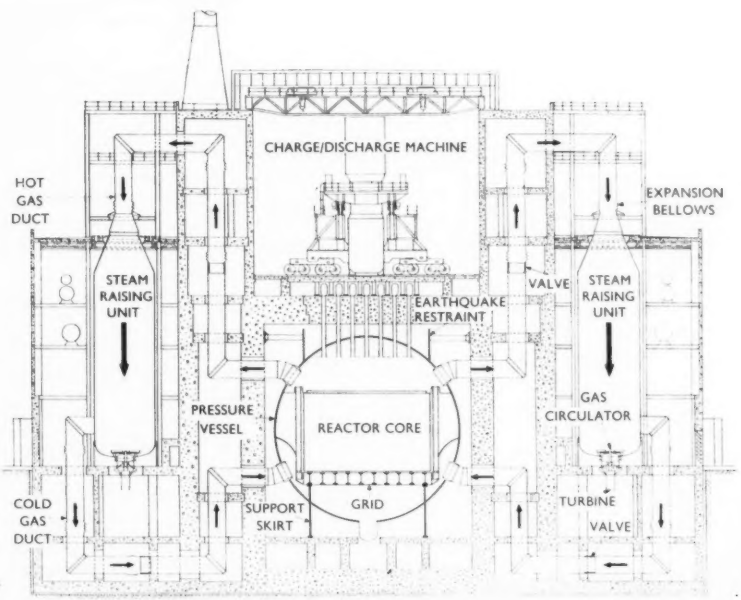
Electrical output of the station will be 150 MW and the source of power will be one gas-cooled graphite-moderated reactor serving four boilers (or steam raising units). The reactor will be of the same basic design as the two being built at Hunterston, the chief differences being modifications introduced to make the reactor safe for use in an earthquake country. There will also be improvements brought about through normal design progress.

Principal departure from the Hunterston design will be the placing of the fuel loading and control rod mechanism at the top of the reactor vessel instead of underneath it. This is to keep the reactor building as squat and the centre of gravity as low as possible as a precaution against earthquakes. Having the charge machinery underneath necessitates a taller building.

Special precautions will be taken to prevent the displacement of the graphite during an earthquake and extra control facilities are provided to ensure feasibility of shutdown of the reactor even when the reactor core is at an angle of 45°. Months of study have gone into designing means of overcoming problems brought about by earthquakes, much of this work being carried out with the aid of models and simulated earthquake conditions.

The station will take about four years to build and is expected to be in operation by mid-1963.

The Japan Atom Energy Co., has been studying and negotiating for a nuclear power station for some two years. A decision to build a gas-cooled graphite moderated reactor station was made after careful consideration of other types, principally those advocated by the U.S.A.



Based on the Hunterston design, the reactor proposed by the GEC for the Tokai Mura nuclear power station will include special structural arrangements and other modifications to safeguard against earthquakes. For instance, the charge/discharge machine is placed on top of the reactor core instead of underneath, as at Hunterston.

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ISOTOPES ASSIST SEWAGE ENGINEERS

Experiments at London Sewage Works

Sedimentation tanks at the Northern Outfall Works, Barking

ENGINEERS for years have been seeking an accurate method of tracing liquid movement in the tanks of sewage treatment plant. The study of such movement can be of great assistance to the designers of new plant, but a suitable tracing material has been found only since the introduction of radioisotopes.

Various materials tried out as tracers before radioisotopes became available include sodium chloride, potassium chloride, fluorescin and methylene blue. All have disadvantages that make their usefulness limited. The dyes, for instance, are adsorbed, in greater or lesser degree, on suspended material, and may be subject to fading in sunlight.

The usefulness of inorganic salts is limited to the extent to which they can be accurately estimated, and in the case of chlorides, by the fact that these already occur in sewage in varying amounts. For this reason, in large-scale experiments, the quantity of inorganic salts necessary to yield reliable results is so large that errors due to density variations are unavoidable.

Large Scale Best

In spite of the disadvantages, however, a great deal of useful work has been done in small-scale tanks with these materials as tracers, and much invaluable information gained. Nonetheless, the scaling up of results obtained in small tanks can never be satisfactory, despite the faith placed in it in certain quarters. Accurate information can be obtained only on large-scale tanks operating under normal, if controlled, conditions. Radioisotopes as tracers have the advantage that they can be detected easily, accurately and unmistakably. In addition they can be used in such dilution that only a few grammes of the material is necessary to label the contents of even the largest sewage tank.

Some Disadvantages

Against these advantages there appears to be some disadvantages. The necessary equipment is relatively expensive, the material to be handled is dangerous, some training in the handling and use of radioisotopes is desirable and the amount of activity discharged into the river must be kept within prescribed limits.

Dr. Stanley Burgess, scientific adviser to the London County Council, and Mr. Arthur Green, principal public health scientific officer to the council, who have carried out some invaluable work with radioisotopes at the Northern Outfall Works, Barking, surmounted these disadvantages without too much difficulty. They kept their costs, for instance, within reasonable limits by selecting their equipment carefully, so that it yielded the maximum usefulness, and by constructing any special items they required in the laboratory.

Danger in handling radioisotopes was reduced to a safe level by using remote handling tools and by the provision of adequate protective lead shielding.

The Northern Outfall Works discharges into the tidal portion of the River Thames in Barking Reach. Here, immediate dilution is very great and no water is removed for human use. By using short-lived radioisotopes, activity in the river can be kept well below drinking water standards. There was thus virtually no discharge problem.

The first experiment carried out by Dr. Burgess and Mr. Green using a radioactive tracer was in an investigation on a large tank improvised for sludge digestion. Phosphorus-32 was used as tracer and the experiment showed that the tank had silted up to about 50 per cent. of its capacity. This was confirmed to a remarkable degree when the tank was opened up.

Continuity Desirable

Because the results from this experiment were so encouraging it was decided to explore the possibility of using the radioactive tracers in other tanks at the works.

A consideration of the problems involved showed that for most of them at least it would be desirable to obtain continuous readings of counting rates in the liquid rather than to examine individual samples. It was decided, therefore, to use a ratemeter rather than a scaler and of the various types available an instrument operating a pen recorder was acquired.

The question of counter heads was a very different matter. The essential requirements of a head were that it should be watertight, efficient and capable of being operated at a

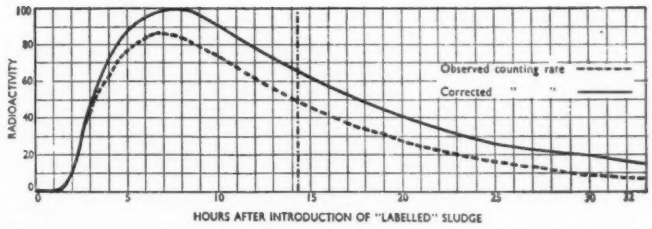


Fig. 1.—Rate of removal of " labelled " sludge from No. 1a re-aeration channel

distance from the ratemeter. In addition, it was considered desirable that the head should be of robust construction and the cables armoured.

Home-made

Counter heads conforming to these requirements are obtainable commercially, but at such an expense that Dr. Burgess and Mr. Green decided to build their own counter head. The head itself consisted of a Geiger-Muller tube followed by a conventional cathode follower valve. Because the heater of this valve had to be fed with low-voltage current it was possible to use only 25 ft of cable before the voltage drop became excessive. The whole unit was sealed in a 2 in. Perspex tube by means of a cork, the supply cables passing out through the cork. The cost of this head came to no more than £10 and the head proved perfectly satisfactory in use.

The first experiment using the head was carried out in a re-aeration channel of the activated sludge plant. The channel is 289 ft long, 15 ft 4 in. wide and 10 ft 6 in. deep with ridge and furrow aeration in the bottom. It is end fed and the re-aerated sludge spills into a narrow weir chamber. The counter head was placed in the channel about 18 in. upstream of the outlet weir, where it would be counting in the maximum possible volume.

In considering the isotope to be used in this experiment, one having a short life seemed to be essential, for three reasons:—

(i) In the large volume of liquid involved a high level of activity would have to be used if the necessary degree of accuracy were to be obtained.

(ii) The risk of serious contamination on the works had to be kept as low as possible.

(iii) The material would ultimately be discharged into the river.

It seemed that either bromine-82 or sodium-24 would fulfil these requirements. Because the half life of sodium-24—15 hours—was considered too short to be satisfactory, it was decided to use bromine-82. This has a half life of 36 hours.

The isotope was delivered as 5g of ammonium bromide, with an approximate activity of 180mc/g. This was dissolved in a litre of 50 per cent. ammonium bromide solution to act as an inactive carrier, and the solution mixed with activated sludge in a bucket and then tipped quickly into the middle inlet of the tank. The recorder was started up almost immediately.

The experiment was continued for more than 30 hours, by which time the rate of counting had twice decreased by half. Over this prolonged period the decay factor of the isotope had an appreciable effect on the results obtained and it was necessary to introduce a correction factor into the curve. Both curves are shown in Fig. 1 and it will be seen that the corrected curve falls from almost its peak exactly exponentially, indicating that the radioactive material was being diluted at a constant rate and that mixing was uniform.

The second experiment was designed to estimate as near as possible the rate of removal of activated sludge from circular settling tanks. The tank used is 98 ft in diameter and 11 ft 6 in. deep to water level, with a centre inlet and radial flow. Mechanical scraping is effected by blades mounted on four arms at right angles, designed to sweep the whole of the slightly sloping floors in two revolutions.

For the purpose of this experiment it was desirable to label the activated sludge selectively from the supernatant. Chromium-51 was used. Laboratory experiments showed that after one hour 80 per cent. of the isotope was adsorbed on the sludge, and after two hours, 95 per cent. Furthermore, after seven days no measurable amount of activity returned to the supernatant.

The isotope was delivered as 2.5g of sodium chromate having a total activity of 425mc. It was dissolved in 200 ml of water, together with 20g of inactive chromate carrier, and

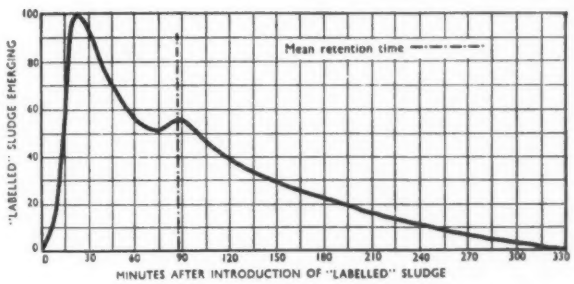


Fig. 2.—Removal of activated sludge from No. 10 circular tank

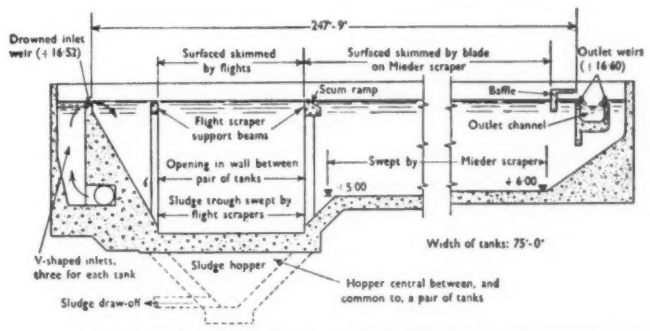


Fig. 3.—Longitudinal section through primary sedimentation tank

added to two gallons of returned sludge about one hour before the experiment was due to start.

The counter head was submerged in the sludge weir chamber. When all was ready the labelled sludge was tipped quickly into the supply channel to the tank, just upstream of the inlet penstock, and the recorder started up. The results, shown in Fig. 2, indicate a mean retention time of 90 minutes. No satisfactory explanation has been found for the occurrence of the little "hump" part-way down the slope of the curve. It happens that it coincided with one revolution of the scraper arms, but it has not been possible to establish any definite connection between the two.

Counter heads being fitted to wires that suspend them in centre of sedimentation tank

Assistant taking readings from ratemeter connected to counter heads suspended in sedimentation tank

Purpose of First Tests

Preliminary experiments carried out on the primary sedimentation tanks were designed to find:—

(1) The level of activity necessary to produce a reliable result;

(2) The most satisfactory point of admission of the isotope;

(3) The most satisfactory method of handling the radioactive material; and

(4) The type of flow-through curve obtained by examining the effluent.

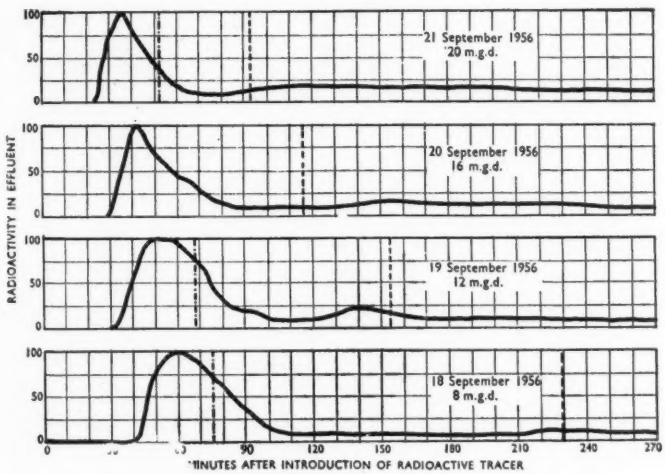


Fig. 4.—Flow of sewage through sedimentation tank at different rates

The tanks are rectangular in shape, 250 ft long, 75 ft wide and 11 ft deep. They are end fed over a weir submerged to a depth of up to 3 in., depending on rate of throughput, and they discharge into a suspended discharge channel. The tanks are constructed in pairs, inter-connected at the inlet end, over the sludge hopper, and have a common feed. During the experiments the floor of the tanks was scraped every two hours by a Mieder-type scraper.

Bromide-82 was used as tracer. The combined capacity of a pair of tanks is 2.58m.gal and assuming all the activity passed the counter heads in about one hour, it was decided that a dose of activity in the order of 1.5c would be required. Ten grammes of the isotope in the form of ammonium bromide of activity of about 150 mc/g were dissolved in 100ml of water and then transferred to a bucket containing two gallons of water in which 200 g of ammonium bromide, as an inactive carrier, had been dissolved. The whole contents of the bucket were then quickly, but carefully, tipped into the supply channel and the recorder started up.

The counter head was immersed in the effluent channel, exactly in the centre, at a point where the whole of the effluent from the channel had to pass it. It was decided to plot the flow of labelled material through the tank at four different rates of flow—8, 12, 16 and 20m.gal/day. Each experiment was run for 4½ hours. The results are shown in Fig. 4.

(*To be continued*)

This article is based on a paper, "The Use of Radioactive Isotopes for the Investigation of Sewage Treatment Plant" recently presented to the Institution of Civil Engineers.

NUCLEAR ENERGY DEVELOPMENTS IN THE

UNITED STATES of AMERICA

Economic nuclear power in the United States presents a challenge to designers because of the large reserves of low-cost conventional fuels and the advanced state of electric power technology. The favourable fuel situation however had given the Americans time to work through a research and development programme on a wide variety of reactor types. Most of the types in operation use enriched fuel and the reactor type with which the Americans have had most experience is that based on the pressurized water concept

by J. BURKETT

THE United States of America has substantial reserves of coal, oil, natural gas and hydro power and the present energy requirements are being met at moderate costs. Even so, electric power consumption is increasing at an average of 7 per cent. per annum (total energy 3 per cent.) and it is apparent that a new source of energy will have to be found eventually to supplement the fossil fuels whose recoverable reserves are not inexhaustible. Whilst there is a less urgent requirement for nuclear power than in most highly industrial countries, there are reasons for its development during the next 10 to 20 years, provided the cost can be kept low. Economic nuclear power in the United States presents a challenge to designers because of the large reserves of low-cost conventional fuels and the advanced state of electric power technology.

The favourable fuel situation has given the Americans time to work through a research and development programme on a wide variety of types of reactor in order to arrive at a suitable reactor for a particular situation either at home or abroad. The development of research reactors and the nuclear power programme has been very much influenced by earlier programmes started 16 years ago, for the manufacture of nuclear materials, when large plants were erected for the production of enriched uranium, heavy water, fuel processing and water cooled reactors. Most of the reactor types in operation or under development use enriched fuel, a policy influenced by the large stocks available from the diffusion plants. Total production of uranium for 1956 was said to be about 3m. tons with estimated reserves of about 60m. tons.

Natural Fuel Likely

Design studies by the Americans have indicated that enrichment improves performance and enables plants to be smaller and less costly. The future programme, however, includes the use of natural uranium with heavy water as moderator and as fuel feed for reactors requiring some enrichment from cycled plutonium.

The responsibility for the national nuclear energy programme lies with the Atomic Energy Commission, an independent agency of the United States Government, established by the Atomic Energy Act of 1946. It succeeded the Manhattan Engineer District of the Army's Corps of Engineers and took over a large system of Government owned laboratories, manufacturing plants and other facilities. The total cost before depreciation of AEC-owned plant and equipment, excluding stockpiles of raw and fissionable material at June, 1958, was $6,839m. The annual cost of operations is now over $2,250m.

Industry Encouraged

The Commission's terms of reference were broadened by the Atomic Energy Act of 1954, particularly for encouraging participation from private industry and international co-operation. Through contractual arrangements, the various government facilities are managed and operated by universities or industrial organizations. The major laboratories operated or supported by the AEC are those at Brookhaven, Oak Ridge, Knolls, Bettis, Argonne, Los Alamos and the University of California. The American policy is to reduce control in nuclear energy development to a minimum consistent with national security, public health and safety; consequently, to create opportunities for private enterprise, the Commission is prepared to reduce its own effort where private concerns prove their capacity and interest.

Whilst AEC employs 6,745* persons, the contractors have 114,308*. In general the Commission supplies the material and services needed by industry only where they are not commercially available. Practically all fuel elements for non-AEC reactors are being fabricated by private industry. Other effort mainly under private enterprise is domestic uranium exploitation, mining and milling, industrial processing and use of radio-isotopes.

The Atomic Energy Commission, which consists of five members appointed by the President for five years, keeps the legislature fully informed through the Congressional Joint Committee on Atomic Energy.

**Employment figures as at December 31st, 1958.*

The many activities of the Commission are operated through a decentralized organization of eight programme divisions, five of which function as operational divisions and have under their supervision major field establishments. These are the Divisions of Production, Raw Materials, Military Application, Reactor Development and of Biology and Medicine. Other programme Divisions include Research, Civilian Applications and International Affairs.

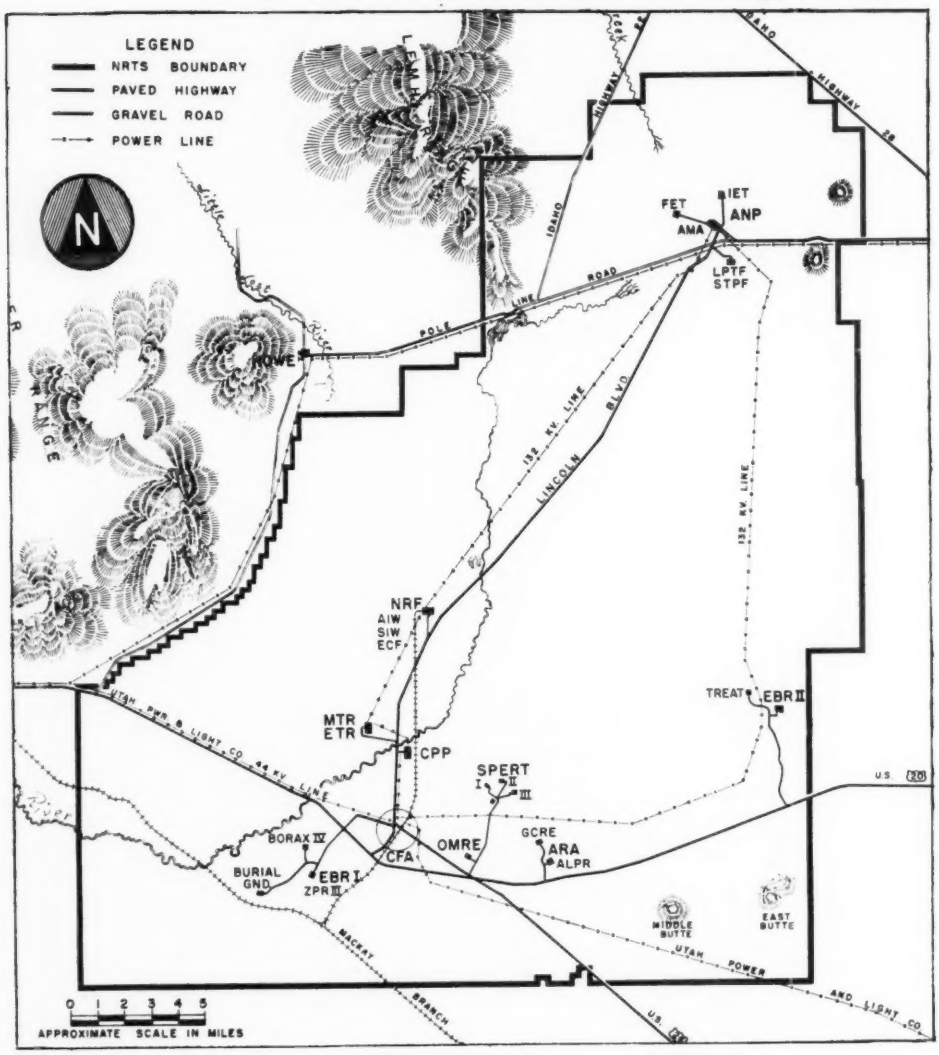
With the ultimate target of developing the technology of somewhat advanced concepts showing greater economic promise, as objectives in the civilian power field for the period 1954–1958, the Commission have under way extensive reactor experiments on five types: the pressurized water, boiling water, sodium-graphite, aqueous homogeneous and the fast breeder systems. Enlargement of this plan includes: BORAX-4, OMRE, LMFRE, ARBOR, LAMPRE, Pu Recycle, and LAPRE.

A.E.C. Subsidized Prototypes

Whilst the construction and operation of full-scale nuclear power plants is recognized to be the responsibility of industry, the AEC is providing financial assistance towards the construction and operation of the first prototype plants in order to induce private enterprise to enter the nuclear power field at a time when such plants are likely to prove uneconomical. This scheme for accelerating the development of commercial power reactors was initiated in January, 1955, when the Atomic Energy Commission announced the Power Reactor Demonstration Programme. A second invitation to industry for proposals on suitable designs in the 5-40 MW power range was issued in September, 1955, and a third in January, 1957, inviting designs with no limit on type or size, completion by June, 1962.

The type of reactor in which the Americans have the greatest experience is the pressurized water concept, where the fuel elements are surrounded by water under high pressure. the water serving as moderator and coolant. The considerable record of successful operation that has been achieved received its impetus from an

The National Reactor Testing Station



Idaho Falls

Established 1949

Area

431,000 acres plus proposed 141,000 acres.

Employees

4,000

Plant investment

+ $165m.

Facilities

17 reactors in operation.

6 reactors being built.

6 other facilities in operation.

4 other facilities being built.

List of Facilities at the Station

Reactors in Operation

Name	Designation
1. Argonne Low Power Reactor	ALPR
2. Boiling Water Reactor No. 4	BORAX-IV
3. Engineering Test Reactor	ETR
4. Experimental Breeder Reactor No. 1	EBR-I
5. Heat Transfer Reactor Experiment No. 2	HTRE-II*
6. Heat Transfer Reactor Experiment No. 3	HTRE-III**
7. Materials Testing Reactor	MTR
8. Organic Moderated Reactor Experiment	OMRE
9. Special Power Excursion Reactor Test No. 1	SPERT-I
10. Submarine Thermal Reactor	S1W
11. Large Ship Reactor	LSR****
(Zero Power)	
12. Critical Experiment	CET***
13. Engineering Test Reactor Critical	ETRC
14. Hot Critical Experiment	HOTCE***
15. Reactivity Measurement Facility at MTR	RMF
16. Zero Power Reactor No. 3	ZPR-III
17. Transient Reactor Experiment Test	TREAT

* Operated in the IET
** Operated in the IET or FET
*** Operated in the Low Power Test Facility
**** Two reactors, one in operation

Reactors Under Construction

Name	Designation
1. Experimental Breeder Reactor No. 2	EBR-II
2. Gas Cooled Reactor Experiment	GCRE
3. Large Ship Reactor B	A1W*
4. Shield Test (Pool) Facility Reactor	SUSIE**
5. Special Power Excursion Reactor Test No. 2	SPERT-II
6. Special Power Excursion Reactor Test No. 3	SPERT-III

* Second reactor
** To be operated in the Shield Test (Pool) Facility

Other Operating Facilities

1. ANP Assembly and Maintenance Area	A&M(ANP)
2. Central Facilities Area	CFA
3. Chemical Processing Plant	CPP
4. Initial Engine Test	IET
5. Low Power Test Facility	LPTF
6. Gamma Irradiation Facility	GIF

Other Facilities Under Construction

1. Expended Core Facility	ECF
2. Flight Engine Test	FET
3. Shield Test (Pool) Facility	STPF
4. Waste Calcination Facility	WCF

extensive naval programme. The Atomic Energy Commission has spent over $273m. on research, development and construction on the Naval Propulsion Programme up to June, 1956. (The Navy's expenditure from *Nautilus* up to 1958 is $1,500m.) The first land-based prototype for submarine propulsion commenced operation in 1953. The sea-going version, used in the *Nautilus*, was put into operation in 1955. Similar reactors are being developed for other naval purposes—13 submarines, a cruiser, an aircraft carrier, etc.

America's First

The first full-scale civilian nuclear power plant to operate in the United States is the pressurized water reactor sited at Shippingport. Delivery of electricity (60 MW) to the Pittsburg area commenced on December 23rd, 1957. Whilst the core is predominantly natural uranium it is "seeded" by the incorporation of a few fully enriched elements. The Westinghouse Electric Corporation, who built the reactor for the Duquesne Light Company, profited from the experience gained from building and operating the submarine prototype.

The Army Package Power Reactor which represents the application of the pressurized water concept to small power plant (1.855 MW electrical), achieved power operation in April, 1957. It was designed primarily for remote military installations, but it has a potential for small central stations in similar remote circumstances. The Americans report that performance has so far been most satisfactory and that the reactor demonstrates a large degree of stability.

Working on the experience so far gained on the pressurized water reactor, Babcock and Wilcox is constructing a reactor at Indian Point, New York, which utilizes a thorium fuel cycle where the core, which will consist of thorium, is seeded with highly enriched uranium. An oil-fired superheater will be used to boost power output. This is a completely private venture by Consolidated Edison Company of New York.

The Yankee Reactor

A third pressurized water reactor, part of the Power Demonstration Programme, similar in design to Shippingport, is being built in Massachusetts by Westinghouse for the Yankee Atomic Electric Company.

Up to 1949 water reactor designers avoided boiling in all the projects under way because it was feared that boiling would introduce intolerable instabilities into the reactor's operation. During this period a number of water-cooled reactors were built with water temperatures maintained below boiling point even under the most severe operating conditions—the Hanford reactors, the Savannah River reactors, CP-5 at Argonne, the Materials Testing Reactor and the Submarine Thermal Reactor.

Argonne National Laboratory conducted laboratory investigations which led to the Borax experiments on a boiling reactor and reported that these experiments showed that boiling did not cause serious instability and that it was technically feasible to couple the reactor to a steam turbine for the production of electricity. Since 1953, when the basic stability in boiling water systems was demonstrated, development has continued with BORAX-4 being the latest in the series. Experiments on the latter indicate that boiling reactors can be safely operated using uranium oxide or thorium oxide as fuel, both being less reactive metallurgically with water coolants than with metallic fuels.

The Experimental Boiling Water Reactor was initiated as a pilot plant boiling water power reactor to test the feasibility of coupling a turbine generator for electricity generation. Since 1956 power levels higher than those designed have been attained and it has been seen that the increased amount of steam in the core did not lead to instability. Residual radioactivity in the turbine apparently has been insignificant. A new and larger core is being designed to increase power level to 100 MW. The project is expected to be completed by the end of 1959. Further basic research on the BWR, particularly on instability, will be carried out on ARBOR in 1960, a facility that will be larger and more flexible than the EBWR.

Dresden Project

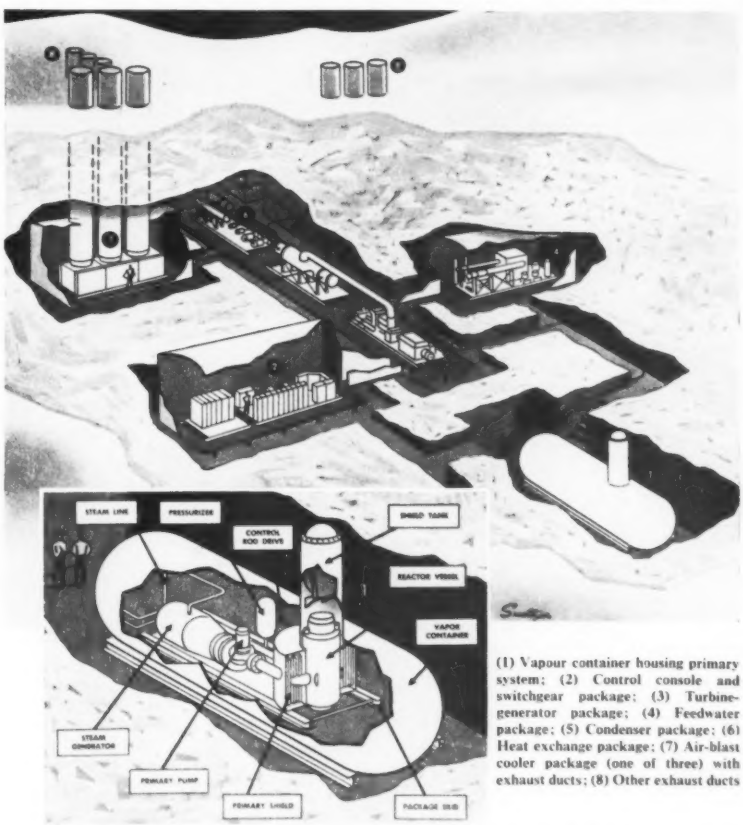
The second boiling water reactor power plant to supply commercial electric power is the Vallecitos BWR built by the General Electric Company primarily to develop information for the design and construction of the Dresden Plant of Commonwealth Edison Company. Unlike the EBWR, which is a direct cycle plant operating at 600 lb/sq.in., Vallecitos is arranged for dual cycle operation at 1,000 lb/sq.in.

The Dresden station when completed in 1960 will most likely be the first large-scale boiling water reactor plant in the world and the largest all-nuclear plant in the U.S.A. Three other BWR plants for the generation of electricity have been planned to commence operation between 1960 and 1962: Elk River, Sioux Falls and Humbolt Bay station. The latter, which is being designed for the Pacific Gas and Electric Company, will have the largest steam flow using the single cycle principle of any reactor design envisaged so far for electrical power generation.

For Remote Locations

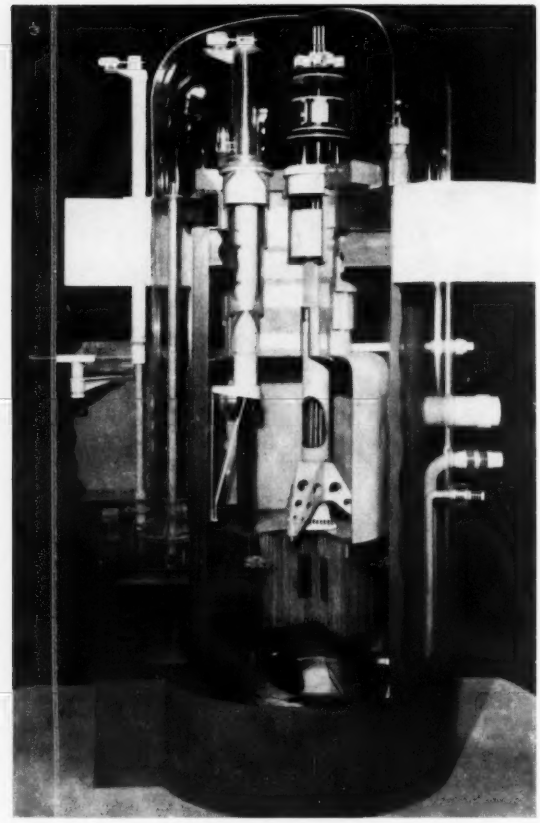
A further experimental facility, the Argonne Low Power Reactor, a small 300 kW(el.) direct-cycle plant, has been designed for use by the military services in remote locations, particularly in the frozen north. The core is specified to last three years before replacement and the complete assembly is designed for installation above ground level.

The AEC believe that heavy water moderated reactors ultimately offer the best promise where natural uranium is to be used as fuel. Research and development on



(1) Vapour container housing primary system; (2) Control console and switchgear package; (3) Turbine-generator package; (4) Feedwater package; (5) Condenser package; (6) Heat exchange package; (7) Air-blast cooler package (one of three) with exhaust ducts; (8) Other exhaust ducts

A sectional drawing of the pressurized water package reactor recently ordered by the U.S. Army from ALCO Products. It is a modified version of the package power reactor built by ALCO for the Army at Fort Belvoir, near Washington, and is similar to the plant being built at Fort Greely, Alaska. Unlike these plants, however, the new one will use gravel instead of concrete for shielding. The use of gravel will enable the plant to be readily moved from one place to another. Output will be about 1,500 kW of electricity for heat and power, plus about 1,000 lb of steam for heating purposes. Fuel will be uranium oxide clad in stainless steel.



Cutaway model of solid-fuel fast breeder reactor for the Enrico Fermi power plant being built near Monroe in Michigan

pressurized concepts is being conducted at Savannah River where extensive experience with heavy water systems has already been gained through the operation of heavy water production reactors. The present programme, however, aims at developing a plant that could take advantage of enriched fuel and also be capable of reasonable operation on natural uranium.

Two Power Demonstration projects are being studied, the Carplinas-Virginia proposal for a pressure tube type reactor using enriched uranium and the East Central-Florida high temperature, gas-cooled heavy water moderated, pressure tube type using slightly enriched uranium. The former was scheduled for 1962 but relaxation of the target date is being considered to allow further research and development.

A lot of research has been done, since experiments were started at Argonne in 1945, on the use of liquid sodium as a coolant. The Knolls Laboratory (GEC) have also carried out extensive research which led to the system used in the nuclear submarine *Sea Wolf*. It is learned, however, that although the vessel has operated satisfactorily over 30,000 miles, the Board of Inspection and Survey trials recommended that the sodium plant be ultimately replaced with a PWR.

Atomics International applied sodium cooling to the graphite-moderated reactor, experiments which led to the construction of the Sodium Reactor Experiment representing the commencement of the sodium graphite power reactor programme. Experience gained with this system will be used as the basis of the Hallam design, a full-scale civilian reactor. Improvements over the SRE which have been planned are the use of oxide fuel elements and zircaloy-2 or stainless steel moderator cans. A further industrial project moderated by heavy water has been proposed by the Chugach Electric Association for the generation of 10 MW of electrical power at Anchorage in Alaska.

Fast Breeder

Fast breeder reactors commonly use sodium as a coolant. Early work on these started in 1945 at Argonne and Los Alamos. The Experimental Breeder Reactor No. 1 which was designed primarily to study the physics and breeding characteristics of fast reactors is also being used for research on liquid metal technology. The world's first electricity from nuclear energy was produced by this reactor in December, 1951. EBR-2 will use full-sized components in its sodium system and it will have operating characteristics similar to those of a full-scale power plant. It will be fuelled initially with uranium-235 but later with plutonium.

The Enrico Fermi nuclear power plant, a solid-fuel fast breeder under construction near Monroe in Michigan, is based on the operating experience of EBR-1 and follows closely the design experience of EBR-2. Fuel elements will be of an enriched uranium-molybdenum alloy clad with zirconium, liquid sodium being used both in the primary and secondary circuits.

Plutonium as Fuel

An advanced experiment in fast reactor design is the Los Alamos Molten Plutonium Reactor which will use molten plutonium as a fuel. It is primarily a short-term project for the development of methods for containing the highly active molten fuel.

Another approach to the breeding problem is the aqueous homogeneous reactor where the uranium fuel is dissolved in either sulphuric or phosphoric acid solutions using either light or heavy water. Much of the experimental work on this kind of system so far has been the responsibility of the Oak Ridge Laboratory. HRE-1 which commenced operation in 1952 established the scientific feasibility of this concept and it was followed in 1957 by HRE-2. It had been hoped to circulate fertile material in the blanket but it appeared to be impracticable, consequently a heavy water blanket is now being used. Plans are proceeding for HRE-3. HRE-2 was designed as a two-region forced circulation reactor but, since a shut-down due to an internal leak in the zircaloy core vessel, it has been operating single-region. Both these systems have used sulphuric acid as the uranium fuel solvent. Experiments using phosphoric acid as an alternative have been undertaken on LAPRE-1 and -2 at Los Alamos. The first experiment was abandoned through excessive corrosion.

Two full-scale HAR power plants have been proposed, the Pennsylvania Advanced Project and Wolverine. The latter idea has since been dropped on the grounds of little or no economic promise.

Organic Moderated

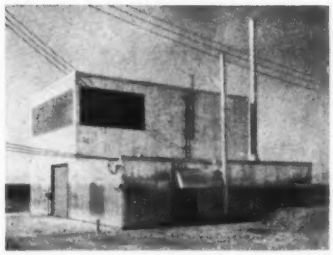
Investigations into the use of organic substances as a moderator of hydrogen atoms instead of water were commenced in 1955. There appeared to be attractive properties: non-corrosive, low level of radioactivity created by neutron bombardment, low pressure at operating temperature. A major disadvantage, however, was thought to be decomposition under radiation possibly leading to fouling of fuel element and heat transfer surface. The Organic Moderated Reactor Experiment was undertaken to determine the rate of organic decomposition and to evaluate possible fouling.

As part of the Power Demonstration Programme, Atomics International have proposed an OMR power plant for Piqua in Ohio. Contract negotiations have been delayed so far through the disapproval of the Reactor Siting Committee.

Research on the use of liquid metal fuel systems is under way at Brookhaven, and as a step towards the development of a large reactor, a basic facility is being provided in the form of a 5 MW(thermal) LMFRE-1. This will use a fluid fuel of uranium dissolved in molten bismuth with unclad graphite as moderator.

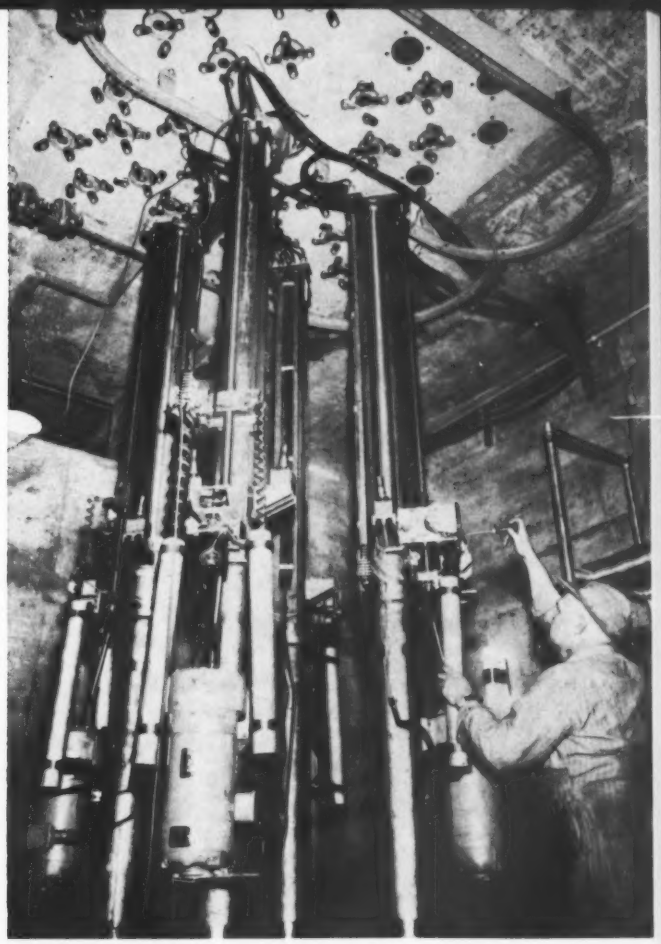
Studies on the high-temperature gas-cooled reactor are being pursued by Oak Ridge, Kaiser Engineers and ACF Industries, particularly on a concept using partially enriched fuel with an outlet gas temperature of 1,000 F. In response to the AEC's invitation to submit proposals for a graphite moderated gas cooled reactor to be completed by the end of 1962, a proposal came from a group of more than 50 utility companies headed by the Philadelphia Electric Co. The group has specified a 40 MW reactor, helium cooled, giving an exit gas temperature of 1,380 F. with graphite canned fuel elements. A

TREAT



TRANSIENT REACTOR TEST FACILITY

Argonne National Laboratory's Transient Reactor Test Facility (TREAT) at the U.S. Atomic Energy Commission National Reactor Testing Station near Idaho Falls, Idaho, recently went critical with 146 fuel elements containing 5.38 kg of U-235. The reactor is designed to produce short, extreme pulses of nuclear energy for the destructive testing of fast reactor fuel elements and components. It will also provide a versatile irradiation tool for studying a number of other problems. Early studies with the reactor will be aimed at determining the effects of extreme pulses of nuclear energy on prototype fuel pins for the Experimental Breeder Reactor II (EBR-II), now being built for the Commission at the



National Reactor Testing Station. A programme of metal-water experiments is also anticipated. TREAT is fuelled by uranium oxide dispersed in graphite. Fuel assemblies are almost 9 ft in length and consist of an upper and lower graphite section and a 4 ft central section of uranium oxide-bearing graphite. This section contains six 8 in. long fuel blocks canned as a unit in zirconium alloy. The end sections are canned in aluminium. Surrounding the fuel core a neutron reflector is made up of graphite blocks taken from two of the world's pioneer nuclear reactors, Chicago Pile 1, built at the University of Chicago in 1942, and Chicago Pile II, a bigger reactor constructed near Lemont, Illinois. Approximate cost of TREAT and associated buildings was 1m. dol. Photographs show the TREAT building (*top*), a technician checking the solenoid-operated latch of a control rod drive during installation of the reactor (*above*), and a scientist directing the lowering of a fuel element through the radial slot in the rotating plug on the reactor top (*left*).

proposal for a prototype heavy water moderated gas-cooled reactor from the East Central-Florida West Coast Nuclear Groups, having a 50 MW (electric) output, is awaiting legislative authority.

Work is proceeding at Hanford Works to demonstrate the feasibility of recycling plutonium as a fuel in thermal heterogeneous reactor systems. Construction of the Plutonium Recycle Test Reactor started in 1958 and when completed it will be used to test plutonium fuel elements in conjunction with the Materials Testing Reactor which will provide data on full charges of plutonium-aluminium alloy fuel elements.

The following descriptions of American reactors have appeared in NUCLEAR ENERGY ENGINEER: SRE, Sept., 1958, pp. 280-1; Vallecitos and Dresden, August, 1958, pp. 232-4; Enrico Fermi—reactor vessel, July, 1958, pp. 182-5; Engineering Test Reactor, July, 1958, pp. 187-9; Shippingport PWR, June, 1958, pp. 152-4; and the Argonne Low Power Reactor, January, 1959, pp. 25-29.

Further details can be obtained from the following papers presented at the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1958:—

P/414 Engineering Test Reactor.
P/415 30 MW GEC Test Reactor.
P/417 MIT Research Reactor.
P/1043 A generalized atomic energy programme.
P/1076 Highlights of nuclear power development in U.S.
P/2161 Nuclear power programme of investor-owned electric utility companies.
P/2163 Economic setting for nuclear power and heat development.
P/452 SRE operating experience.
P/450 Design study for a graphite-moderated gas-cooled reactor using partially enriched uranium.
P/608 Sodium Graphite Reactor Power Plant for CPPD.
P/610 Heavy water moderated and cooled power reactors.
P/1038 The Yankee atomic electric plant.
P/1543 Aqueous homogeneous type research reactors.
P/449 HRE-2.
P/1885 Consolidated Edison Co. of N.Y. nuclear electric generating station.
P/1926 Design and operation of the APPR-1.
P/421 OMRE
P/1075 Experience with U.S. nuclear power reactors.
P/2462 Shippingport Atomic Power Station (PWR).
P/1792 Design, construction and operation of PWR.
P/1891 Containment for the EBWR.
P/1782 EBR-II.
P/1923 Operation of a high performance light water boiling reactor.
P/1892 Containment of EBR-II.
P/1852 Controlled recirculation BWR with nuclear superheater.
P/1850 Enrico Fermi Atomic Power Plant.
P/2427 Appraisal of the Enrico Fermi Reactor.
P/2177 Technical and economic aspects of MTR and ETR operation.
P/2379 Direct cycle BWR based on EBWR and BORAX.
P/2021 Plutonium fuels for fast reactors.
P/1078 Fuel enrichment and reactor performance.
P/1116 Fuel cycles in single-region thermal power reactors.

'NUCLEARIST' writes . . .

THE cat was certainly put among the pigeons on the occasion of the first transaction under the nuclear common market. As a batch of ruthenium-103 arrived in Rome from France, Professor Felice Ippolito, Secretary-General of the National Committee for Nuclear Research, vented his spleen in no uncertain manner, and I am told that the echoes are reverberating down several government corridors. It seems that the Italian nuclear programme is in danger of foundering on the reefs of poor organization, and the government is accused of failing to institute nuclear legislation, of adopting an unrealistic attitude, and of parsimony in financing nuclear developments. Now, Ippolito speaks with authority, and can hardly be accused of lack of a sense of responsibility, so his words must carry weight. For such an accusation to be levelled at a government on the dawn of the country's nuclear future does not inspire confidence, but at least there seems to be a real possibility that it is already having some effect.

There are some who have asked why Ru103 was wanted in Italy. This isotope is one of the principal products of the fission of uranium-235, and until radiochemistry came to stay, there was a very inadequate knowledge of the element. Having been intimately concerned with fission products research, I can say without hesitation that I was one of those chemists who found this element both fascinating and bewildering. Those people who have experience of fuel reprocessing and plutonium extraction will be very much aware of the vagaries of this strange metal, which shows a versatility in its chemical reactions almost unequalled among the elements. It is less of a mystery now, but there is still plenty of room for research.

* * *

The free city of Bremen has a proud tradition lasting well over 1,000 years, since it was in 788 that Charlemagne made it a bishopric. Much of the history of this grand old Hanseatic city has centred around its wonderful City Hall, or Rathaus, and one of the traditional festive occasions held annually there is the Schaffermahlzeit. This year the guest of honour was Professor Siegfried Balke, Germany's Minister for Atomic Affairs. To an audience of 250 shipowners and their friends, he recalled Bremen's venturesome past, and spoke of the adventures which still awaited the men of the sea as they looked into the future, with dreams of nuclear ships. Why not regular trade by nuclear ships via short and fast routes under the North Pole? The American submarine *Nautilus* has already shown the possibility of this, and it is a possibility that need not be in the very distant future.

Signs of German awareness of the opportunities in nuclear shipping, in fact, may be seen in the recent award of a contract for research and development for a prototype propulsion unit for an oil tanker. Awarded by the Gesellschaft fur Kernenergie im Schiffbau und Schiffahrt, this contract goes to Interatom, the combine of the American Atomics International and the German Demag, and will involve 2½ years' work. This will provide for a ship of 40,000 tons and 10,000 s.h.p., and operating with a reactor cooled and moderated by an organic liquid.

* * *

German opinion seems to be against the establishment of a European University of Nuclear Studies on the grounds that there are already many universities in Europe. But this argument is hardly sound. After all, if a great institution can be set up in Europe, to which students may be sent for training as nuclear physicists, nuclear chemical engineers, fissile material processing experts, health physicists and the like, then such a university must be fully equipped for the task. The cost would be great, and perhaps beyond the resources of any one European country, though a possibility if it is by joint effort. It is to be hoped that OEEC and Euratom will press on with this plan in spite of the cold water from Germany.

* * *

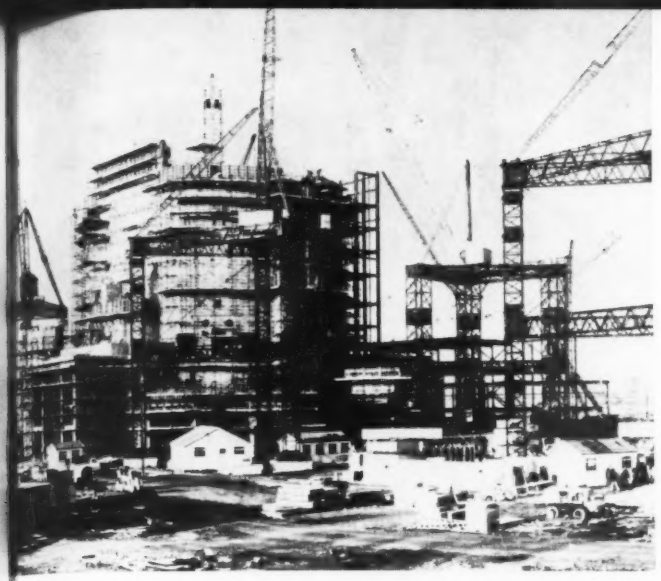
Amadeo Avogadro, an Italian scientist, pointed out in 1811 the distinction between atoms and molecules, and so cleared up many difficulties which had dogged the studies of chemists on gaseous reactions. He also put forward the hypothesis that under similar conditions equal volumes of all gases contain equal numbers of molecules, and this number, equal to 6.0×10^{23} in 22.4 litres at normal temperature and pressure, we call the Avogadro Number. This value is of immense importance to chemists and physicists, and plays its part in nuclear calculations. In honour of the Italian scientist, the name 'Avogadro' is to be given to the 1-5 MW swimming-pool research reactor which is to be supplied by the American firm of A.M.F. to the SORIN nuclear research centre at Saluggice, Italy.

* * *

Another suggestion for the perpetuation of the name of an Italian scientist comes from Alwin Weinberger and Eugene Wigner. These two American nuclear physicists, in their recent book "The Physical Theory of Neutron Chain Reactors," have stated that the name "barn" to the unit 10^{-24} sq.cm, used in nuclear cross-sections, should be replaced by the name "fermi." This is a sound suggestion, and one which I hope will find support with all nuclear workers, even though the change may come a little strange at first. There are so many units named after great scientists that this would be no precedent, and in fact it is rather odd that Fermi's name has not before now been similarly used.

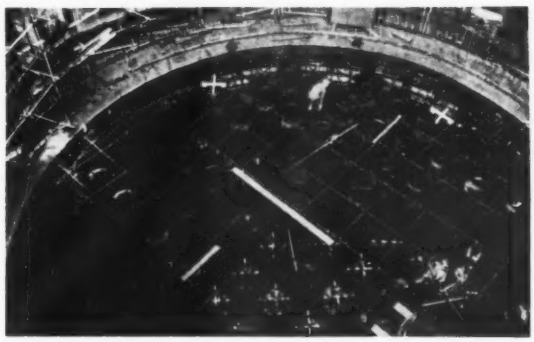
* * *

At the 1955 Geneva Conference contributions from India amounted to only 16 papers; at the 1958 conference there were 58—a sign of the progress made by that country in nuclear work. The establishment at Trombay has now been in operation for two years, and the Indians there are making all their own electronic instruments and other equipment for their nuclear programme, besides isotopes for use in medical, agricultural and industrial research. Trombay employs 800 scientific and technical staff, a number that has grown from the small group which was there when the first research reactor Aspara started up 2½ years ago. The second reactor, Zelina, is due to operate in the middle of this year, and next year comes into working the Canadian-Indian reactor which cost Rs. 75m. India's first atomic power station will commence operations in five years' time, with a power of 20 MW.

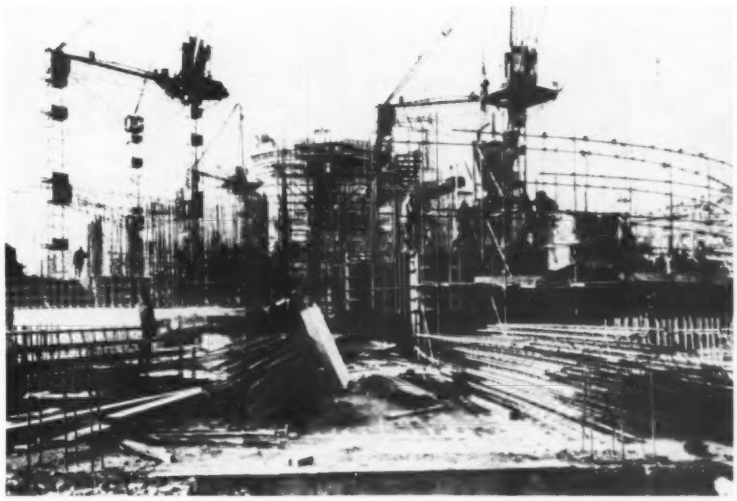


QUARTER OF THE WAY THERE

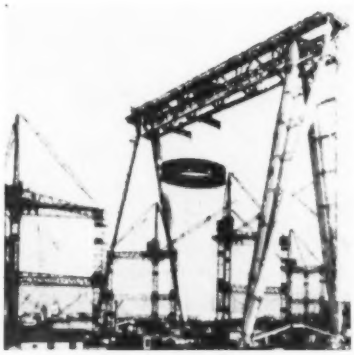
Progress at Hunterston

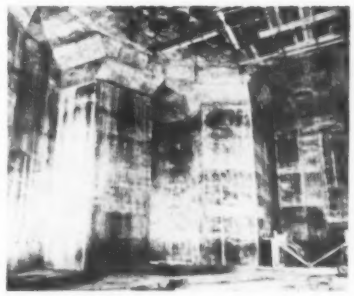


The first reactor building of the nuclear power station being built at Hunterston, Ayrshire, for the South of Scotland Electricity Board by the General Electric Co., in association with Simon-Carves, Ltd., the Motherwell Bridge and Engineering Co., Ltd. and Mowlem (Scotland), Ltd., has reached an advanced stage. The reactor shield walls (*top left*) have now risen about 120 ft above ground level and the supporting skirt for the reactor vessel has been erected inside them. Meanwhile, rapid progress is being made with the civil engineering work on the second reactor, the turbine hall and circulating water system



(*Above*) The standpipe sleeves being placed in position prior to the casting of the biological shield in the first reactor building. (*Right*) The walls of the second reactor building rise above the foundation raft. The first reactor building can be seen in the background





(*Left*) The supporting skirt for the first reactor pressure vessel being lifted into position by the 300-ton Goliath crane. (*Right*) The interior of the chamber in which the charge/discharge machine will operate beneath the first reactor. Part of the lower surface of the biological shield can be seen with the sleeves through which the standpipes will pass

Radiation Balance Microcalorimeter

INSTRUMENT FOR MEASURING ENERGY FROM ACTIVE MATTER

A RADIATION - BALANCE microcalorimeter recently developed by Dr. W. B. Mann of the U.S. National Bureau of Standards precisely determines the emission rate of low-activity radioactive sources. The instrument does this by measuring the minute amounts of heat energy which accompany radioactive emission. The device is extremely compact and requires a relatively short time to complete a determination. It can be used to determine the intensity of a single source or to compare two sources of nearly equivalent energy emission.

A primary function of the U.S. National Bureau of Standards is the custody and maintenance of the national standards of physical measurement to meet the needs of science and industry. The Bureau's first standard of radioactivity was brought to the United States by Marie Curie in 1913. Subsequently two Hönigschmid radium standards were acquired to calibrate and compare all of the radium sources produced and sold in America.

With the development of nuclear energy and the tremendously increased use of radioisotopes, the demand for Bureau certification of radioactive sources increased appreciably. To accommodate this new work, the radiation balance was developed and investigated as a possible supplement to existing instruments. It is capable of rapid, accurate determinations, and is expected to aid materially in the certification work.

First in 1910

A calorimeter embodying the principles used in the new radiation balance was first described by H. L. Callendar in 1910. With this calorimeter, which he called a radio-balance, Callendar made measurements of solar radiation and also carried out a somewhat preliminary measurement of the energy emitted in unit time from a sealed source of radon. Since that time, apart from a determination of the Stefan-Boltzmann radiation constant by Hoare in the early 1930s no other reference to the radio-balance has occurred in the scientific literature.

For measurement of radioactive emission a cup form of the radio balance was designed at the Bureau. This instrument consists essentially of two cups, the temperatures of which are balanced against each other by means of two thermopiles arranged around the equator of each cup and connected in opposition through a sensitive galvanometer. Thus, when there is no difference in temperature between the cups, there will be no deflection of the galvanometer.

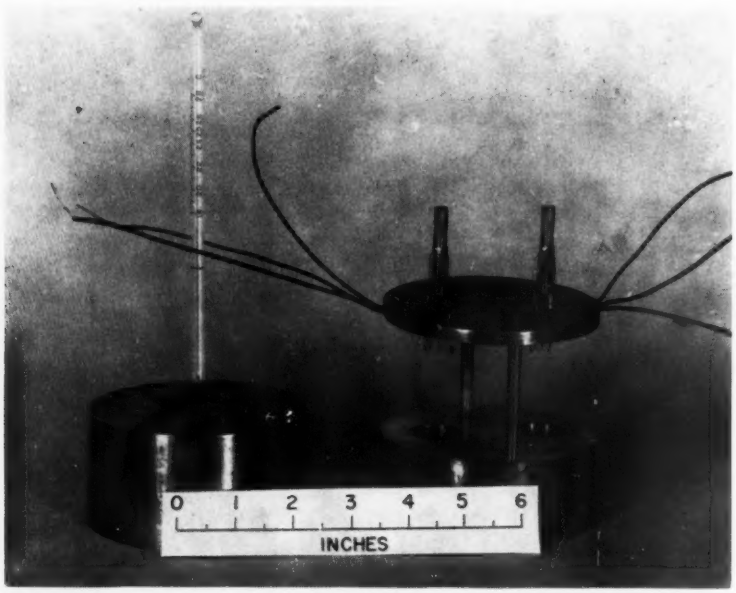
Peltier Junction

A junction of two dissimilar metals, known as a Peltier junction, is soldered to the bottom of each cup. When an electric current is passed through a Peltier junction, heat is either absorbed or generated depending on the direction of the current.

The two junctions are connected in series in such a way that when a current is passed through them one junction cools and the other heats. A radioactive source is placed in cup A, and a current is passed through the junction in a direction such that Peltier cooling occurs in the junction below A and Peltier heating in the junction below cup B. The current can be adjusted (provided that the source of radioactivity has an energy emission below a certain calculable maximum value) so as partially to balance the energy emission in A with Peltier cooling. With the addition of Peltier heating in B, it is possible to achieve a temperature balance between A and B.

When this balance is achieved, there is normally only a small

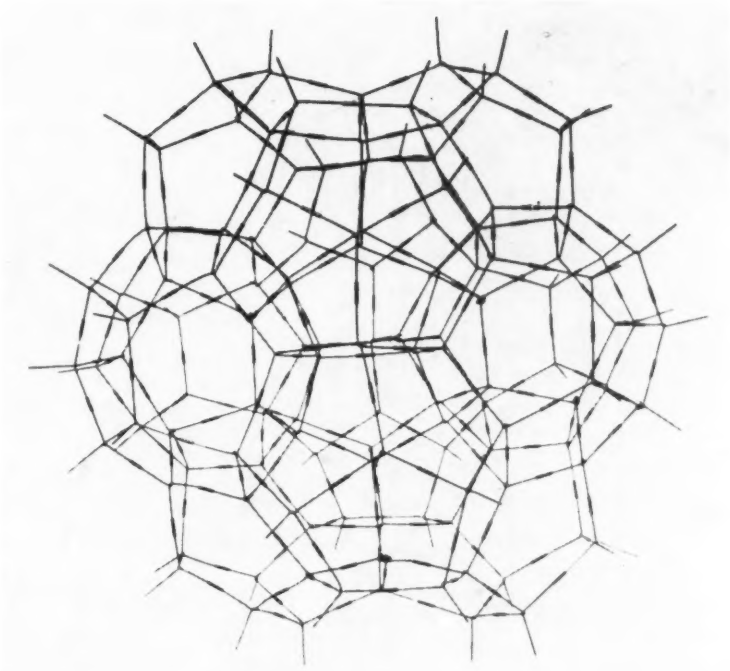
(*Continued on page 208*)



One of the present group of U.S. National Bureau of Standards radiation balances, showing the two gold source cups and their thermopiles on the right. The large copper block and thermometer on the left are placed on top when the balance is assembled for operation

Structure of Matter in "Glassy" State

New Conception of Non-Crystal Atomic Structure



View along one axis of a 13-element vitron model. In this model, a tetrahedron is represented by two wires bent at an angle of 109.5° and soldered at the wire's symmetrical crossing to represent silicon. Oxygen is represented by friction-tight couplings

MR. L. W. TILTON, staff scientist of the U.S. National Bureau of Standards, has recently suggested a new concept of the atomic structure of matter in the glassy state. Based on a structural unit called the " vitron," this concept embraces a non-crystal yet systematic arrangement of atoms over submicroscopic volumes. Such a structure is in accord with available data on the unique properties of glass which set it apart from other types of substances.

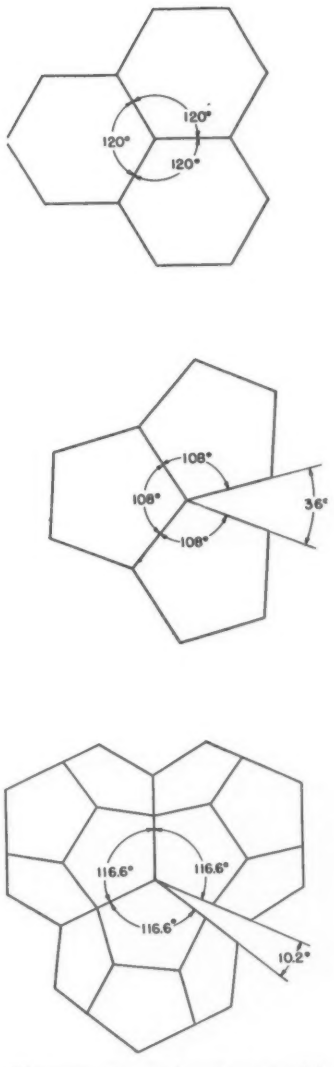
The " vitron " is conceived as a submicroscopic cluster of pentagonal dodecahedra with subunits of silicon-oxygen tetrahedra. Because of their pentagonal shape, the dodecahedra can be fitted together only when slightly distorted, and this ultimately limits the size of the cluster. In the proposed model, the clusters are somewhat loosely joined together by " connective tissues " that have weaker bonds but greater densities than the vitron. This new concept, if corroborated, would help to reconcile current hypotheses on the structural differences between the glassy and crystalline states.

Some Irregularity

The extent of orderly arrangement in the vitron concept is greater than in other hypotheses but some irregularity is retained, especially in the regions where connective tissues unite the clusters. To a certain degree this non-crystal concept is equivalent to the " crystallite " hypothesis as stated by Randall and his workers. They consider silica glasses as continuous networks within which are wide, approximately periodic modulations in density, in stresses, and in the degree of structural regularity.

The proposed model is not inconsistent with known data on such

(*Continued overleaf*)



Diagrams of crystal and non-crystal clusters. Regular pentagonal dodecahedra fail to fill space completely However, by radial compression neighbouring dodecahedra (*lower diagram*) can be distorted so that a limited degree of growth in space is possible

Radiation Balance

(*Continued from page 206*)

residual galvanometer deflection. Since the temperature of cup A is now very nearly equal to that of cup B, the heat losses from the cups, which occur chiefly along the thermopile leads, are essentially equal and compensatory.

This technique may also be used to compare two radioactive sources and can in fact be used to compare two nearly equal sources without the use of Peltier cooling or heating at all. When the energy emission value of a single source is required, it is desirable to use a similar dummy source in the second cup in order that the thermal conditions in the two cups may be essentially the same.

To measure absolute values of radioactive emission, the radiation balance is first calibrated by determining the magnitude of the Peltier effect in the junctions soldered to the bottom of each cup. For this purpose, two small accurately calibrated resistance coils (R and r) were wound on platinum wire to simulate the thermal conductivity of the platinum-iridium needles. The coils are connected in series with the Peltier junctions, so that the same current flows through the coils and the junctions. One coil is then inserted into each cup of the radiation balance, the current is adjusted in magnitude and direction to obtain balance, and the value of the current is determined.

When the galvanometer balance is achieved, a condition exists such that:

$$i^2(R-r) = 2Pi,$$

where i is the current flowing through the coils and the junctions, and R and r designate the resistances of the two coils. The Peltier effect P can be determined directly from this equation.

Emission from Source

For the absolute measurement of the energy emission of a radioactive material, the source to be measured is placed in one cup, and a dummy is placed in the other. When the Peltier current has been adjusted to give a thermopile galvanometer balance, the difference in the energy emission from the sources is equal to the product of twice the current and the Peltier coefficient. Since the energy emission from the dummy is zero, the energy difference is equal in value to the emission of the radioactive source.

Several Balances

A number of radiation balances have now been constructed at the Bureau, and their application to the measurement of the energy emission from radium has been studied. One of these instruments, with cups of gold, has been used to compare the U.S. and British primary radium standards with the Canadian national radium standard. With this radiation balance, the standard deviation of the results was only 0.13 per cent.

The Bureau's radiation balances also have been used to measure the energy output of commercial radium preparations. The instruments are currently being applied to the determination of the branching ratio in the decay of polonium-210 and to the preparation of the Bureau's tritium standards.

Structure of Matter

(*Continued from previous page*)

properties of silica glass as density; differential diffusion of gases; interatomic distances derived from X-ray, electron and neutron diffraction; low tensile strength; anomalous thermal and pressure effects on volume; and internal friction effects at low temperatures. Evidence in support of the concept is given by analyses of property-composition curves for solubility, chemical attack, volatilization, molar volume, and electrical resistance; and from differential diffraction studies of alkali silicate binary glasses.

At Present Similar

Present theories of glass structure view the atomic arrangement and interatomic distances of nearest neighbours in a glass and in its most closely related crystal as being similar. However, in glass, the many slight irregularities, cumulated over relatively long distances (on an atomic scale), are believed to introduce an irregularity that masks the periodicity characteristic of crystals.

Under the vitron concept, glasses and crystals may be expected to differ more fundamentally because of the difference in their structural symmetries. Theoretically, growth in crystals can proceed indefinitely without stress. On the other hand, the vitron—because of its five-fold non-crystal symmetry—is automatically limited in growth by ever-increasing distortional stresses.

Silica Glass Tests

The vitron concept and related ideas on glass structure arose from extensive observations concerning the reversible volume changes in silica glass produced by annealings at different temperatures. According to the vitron concept, these volume changes are caused by a temperature-sensitivity of the bond angles. This is in contrast to theories that attribute the changes to a stretching, or breaking and reforming, of the bonds.

According to the vitron concept, the density of silica substance should range from a low at very high temperatures in the melt to a maximum density at absolute zero. On this basis, approximate limits for the density are 2.0, computed for undistorted elements of vitrons at 2,000°C., and 3.9 at absolute zero for closest rhombohedral packing of oxygen spheres appropriately impregnated with silicon atoms.

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For S. America

TRACERLAB'S reactor monitoring centre in Richmond, California, is building two "retention tank monitoring systems" for the Instituto Venzolano de Investigaciones Ciertificos located in Caracas, Venzuela. The two systems will be used in the institute's new research reactor.

PEOPLE... in the NUCLEAR NEWS

Two newcomers to the board of directors of the General Electric Co., Ltd., are **MR. R. N. MILLAR,** MA(Cantab), BCom, MIMechE, AMIEE, FREconS, and the **HON. S. G. CATTO.** Mr. Millar, who is in overall charge of the mechanical and nuclear activities of the GEC, under Mr. A. L. G. Lindley, assistant managing director of the company, was educated at Marlborough College and, following an engineering apprenticeship at the Erith Works of the GEC, took the Mechanical Science Tripos at Emmanuel College, Cambridge University. During the war he served as an engineer officer in the Royal Navy, and in 1947 was appointed assistant mechanical engineer to the British General Electric Co. in South Africa. While there he took another degree in Economics and Industrial Administration. In 1952 he was transferred to Sydney, Australia, as chief mechanical engineer of the British General Electric Co. Pty., Ltd. Two years later Mr. Millar was recalled to England to take charge of nuclear energy developments in the GEC, and later that year became manager of the GEC-Simon-Carves Atomic Energy Group. Early in 1957 he was appointed assistant general manager of the Erith Works of the GEC and a year later became general manager. Mr. Catto, who was educated at Eton and at Trinity College, Cambridge, is a managing director of Morgan Grenfell & Co., Ltd., the bankers. He is also a director of Yule, Catto & Co., Ltd., and the London Australia Investment Co., Ltd. (Sydney).

The United Kingdom Atomic Energy Authority have appointed **DR. NYMAN LEVIN,** BSc, PhD, ARCS, DIC, FInstP, as director of the Authority's Weapons Group at Aldermaston. He has been deputy director since he joined the Authority

Dr. N. Levin

last summer (see NUCLEAR ENERGY ENGINEER, September, 1958). He succeeds **SIR WILLIAM PENNEY** who is to become Member of Research to the Authority when **SIR JOHN COCKCROFT** takes up the Mastership of the new Churchill College. Dr. Levin is succeeded as deputy director of the Weapons Group by **MR. E. F. NEWLEY,** BSc(Mech.Eng), MSc, AMI MechE, AMIEE, who since 1957 has been chief of Warhead Development at Aldermaston. Mr. Newley, who was educated at London University, was for several years

Mr. E. F. Newley

with the GPO Engineering Department. In 1949 he joined the Admiralty at Teddington as a senior principal scientific officer and in 1955 was appointed deputy chief engineer in the Atomic Energy Authority's Weapons Group.

British Insulated Callender's Cables, Ltd., have appointed **SIR JOHN DEAN,** BSc, ARIC, FIRI, a director of the company.

Chairman of the International Atomic Energy Agency panel of experts on civil liability and state responsibility for nuclear hazards that recently held its first meeting in Vienna is **DR. PAUL RUEGGER,** of Switzerland. A well-known expert on international law, Dr. Ruegger is a member of the Permanent Court of Arbitration and of the Board of the Academy of International Law in the Hague. He was at one time president of the International Committee of the Red Cross. United Kingdom member of the panel is **MR. C. H. CARRUTHERS,** head of the insurance department of the Board of Trade. Other members include **MR. GUISEPPE BELLI,** of the Italian Ministry of Industry and Commerce; **MR. EDWARD DIAMOND,** legal adviser to the U.S. Atomic Energy Commission; **MR. B. N. LOKUR,** joint secretary and legal adviser to the Indian Ministry of Law; **MR. SEIZO NAGASAKI,** a marine insurance expert and member of the Japanese Insurance Industrial Forum and Atomic Energy Commission; **MR. FUAD ABDEL MONEIM RIAD,** professor of international private law at present lecturing at Khartoum University; **MR. PAVEL WINKLER,** director of the bureau of Legal Affairs of the Czechoslovakian Foreign Ministry and former IAEA chairman, and **MR. ENRIQUE ZALDIVAR,** professor of comparative law and member of the Argentine Atomic Energy Commission.

MR. A. R. COOPER, MEng, MIEE, MInstF, a full-time member of the Central Electricity Generating Board and director of the Board's Eastern, London and South Eastern Region, is to take up special responsibilities for the operations (including nuclear) and personnel work of the Board. Upon taking up these duties, he is relinquishing his position as regional director. **MR. A. E. HAWKINS,** BSc(Eng), AMIEE, at present system planning engineer of the Board, will take up the appointment of chief operations engineer and will be responsible direct to Mr. Cooper for operations including National Control. **MR. S. S. SCOTT,** MA(Oxon), chief personnel officer, will also be responsible direct to Mr. Cooper. Succeeding Mr. Cooper as director of the Eastern, London and South Eastern Region is **MR. H. J. BENNETT,** AMIEE, FBIM, previously deputy director of the Region and controller of the London Division. The latter post is now filled by **MR. L. W. STRETTON,** MIEE, chief generation engineer of the Eastern Division. **MR. P. W. CASH,** BSc(Eng), ACGI, MIEE, previously system operation engineer at Headquarters, is now system planning engineer.

New assistant superintendent of the maintenance department of Metropolitan-Vickers Electrical Co., Ltd., is **MR. J. F. HANCOCK.** After receiving a technical education at the Head Technological College, Dublin, Mr. Hancock served an apprenticeship in mechanical engineering, and then held positions with various firms, in each case on the works engineering side. The last of these, prior to his joining Metropolitan-Vickers in 1958, was with the Dayton Corporation, of Dayton, Ohio, for whom he was responsible as plant engineer for the development and maintenance of their new factory in Scotland.

DR. ERNEST LUSTIG, who recently joined the staff of the U.S. National Bureau of Standards as a physical chemist in the Molecular Structure and Properties of Gases Section, was formerly with Sylvania Lix-Klett, Argentina, and E. I. Dupont de Nemours & Co. Born in Gleiwitz, Germany, Dr. Lustig attended the University of Buenos Aires on a university fellowship. He received a Doctor of Chemistry degree in 1948, and taught physical chemistry there for two years. In 1957 he received his PhD in physical chemistry from the Massachusetts Institute of Technology.

MR. M. SOFFA, ASMA, general manager of Jeltek, Ltd., manufacturers of industrial protective clothing, has been appointed to the board of directors. He will continue as general manager.

Thos. W. Ward, Ltd., recently announced the appointment of **MR. ARNOLD CARR** as chairman of the three Ward subsidiaries, Thomas Smith & Sons (Rodley), Ltd., John Smith (Keighley), Ltd., and Widnes Foundry & Engineering Co., Ltd.

NUCLEAR NEWS

- **U.K. Firm's Research Reactor** *(This page)*
- **Heraldic Exercise** *(Page 211)*
- **I.A.E.A. Chief in New York** *(Page 212)*

A 10 kW research reactor for use as a training facility in universities and other teaching centres is to be put on the market by the Hawker Siddeley Nuclear Power Co., of Langley, Bucks. Called the JASON, it will be based on the ARGONAUT reactor designed by the Argonne National Laboratory at Lemont, Illinois. A prototype JASON is to be built at Langley to start operating in September. This unit will not only act as a demonstration model for the purpose of assisting the company in obtaining orders for the reactor, but also will provide the company with an extra facility for their existing research into nuclear power applications. The reactor will be of the thermal heterogeneous type, having an annular core with internal and external reflectors and with water moderation. The maximum flux will be about 1.5×10^{11} neutrons/sq.cm/sec at a low power level of 10 kW. Fuel elements used will be similar to those used in DIDO and PLUTO at Harwell. With JASON, which is a simple and inherently safe reactor, it will be possible to carry out many nuclear physics experiments, produce isotopes, carry out neutron therapy and undertake research into radiochemistry.

Thermonuclear Talks

A TWO-DAY conference on thermonuclear power research, organized by the British Nuclear Energy Conference in London during April, will include descriptions not only of U.K. work in this field but also of U.S. and Russian work. Subjects to be discussed at the various sessions will include the basic physics of thermonuclear processes, U.K. prototype development work on machines such as ZETA and SCEPTRE.

Site Searching

THE Central Electricity Generating Board is to investigate a number of areas on the coast of Anglesey to see how far they are suitable for nuclear power station sites. They are at Lligwy, Point Lynas, Wylfa, Carmel and Trefadog. Investigations will include ground surveys, trial borings and hydrographic surveys and will take probably several months to complete. The earlier investigations in North Wales were directed to finding a site for the first nuclear power station that could share the 275,000v transmission line being provided from the Ffestiniog pumped storage station to Connah's Quay in Flintshire; additional transmission in North Wales could thereby be kept to a minimum at that stage. The Anglesey coast did not come into the picture because of transmission remoteness from Ffestiniog. A site at Trawsfynydd in Merionethshire was eventually selected, and a site at Edern in Caernarvonshire was nominated as suitable for the future. The second power station in North Wales will need entirely new transmission lines and any suitable site in Anglesey will need to be considered along with that at Edern. The Board is also to investigate two areas on the central south coast of England as possible nuclear power station sites. These are at Earnley in West Sussex and at Hamstead on the Isle of Wight.

Power Convention

" PROGRESS on the first nuclear power stations—Bradwell, Berkeley, Hinkley Point, Hunterston " will be the subject of one of the papers to be presented at the 11th British Electrical Power Convention at Torquay, June 1st-5th. Authors of this paper will be Mr. F. S. Brown, BSc, MIMechE, MIEE, member of the Central Electricity Generating Board, and Mr. J. Henderson, MC, BSc, ARTC, MIEE, chief engineer of the South of Scotland Electricity Board. Other papers will deal with industrial, commercial and domestic electrical progress, electrical contracting in all its aspects, safety in the home, and the development of light sources. President of the convention will be Mr. C. R. King, CBE, ComplEE, MInstF, deputy chairman of the Central Electricity Generating Board.

U.S. N-Congress

OVER 250 papers on the peaceful uses of nuclear energy will be presented at the Nuclear Congress to be held in Cleveland, Ohio, during the week April 5th to 10th. The papers will cover reactor design, power plants, radiation techniques, instrumentation, shielding, waste disposal and other related items. The congress is organized by the Engineers Joint Council and sponsored by 30 engineering, scientific and other organizations. Held in conjunction with the congress will be the Atomfair, sponsored by the Atomic Industrial Forum Inc. It will be supported by over 100 exhibitors, among them being Pye Ltd., of Cambridge, and Vickers Engineering Ltd.

"N-Smashing" Order

METROPOLITAN-VICKERS Electrical Co., Ltd., have secured an order against world competition for a 40 MeV electron linear accelerator from the city of Hamburg. The machine is for Deutsches Elektronen-Synchrotron (DESY), Research Group, Hamburg. The value of the order is about £250,000. The accelerator will be used to inject a beam of 40 MeV electrons into a large electron synchrotron which will then further accelerate the electrons to an energy of 6,000 MeV. To make this further acceleration possible, very rigorous restrictions are necessary on the output of the linear accelerator used for injection. Thus, very little variation is permissible on the specified 40 MeV energy, and the electron beam must be compact, i.e. small in diameter, and must have very little divergence. The linear accelerator, which is of the travelling wave type, will be energized by short wavelength radio-frequency power, and the electrons will be accelerated along a specially shaped waveguide. The equipment will have an overall length of approximately 35 ft, and comprise five sections of accelerating waveguide, each $1\frac{1}{2}$ m long, together with an electron gun and prebuncher at the injector end. Each accelerator section will be fed by a high power klystron, also manufactured by Metropolitan-Vickers Electrical Co. Ltd.

Metal Protection

A SYMPOSIUM on metal protection is being held by the Metal and Plastic Coatings Association on April 17th at the Charing Cross Hotel, Strand, London. Papers to be presented will include " Metal Spraying in the Protection of Iron and Steel " by Dr. T. P. Hoar, of the department of metallurgy, Cambridge University; " Painting Sprayed Metal Coatings " by Dr. L. A. Jordan of the Research Association of British Paint and Varnish Manufacturers, and " Plastic Coatings " by Dr. H. B. Footner, of Shell Petroleum Co., Ltd., and Mr. N. Vinson, of Durable Plastics Ltd. There will also be a display of technical exhibits provided by association members showing research, method of application and applications for metal and plastic coatings.

Professorial Tours

ARRANGEMENTS have been made with the Foreign Office, the Board of Trade and the nuclear energy consortia for Professor W. Murgatroyd, professor of nuclear engineering at Queen Mary College, London, and Professor J. M. Kay, professor of nuclear power at Imperial College, London, to carry out lecture tours in eight Latin American countries under the sponsorship of the British Council. They will lecture to engineers and scientists on British nuclear development and aims and the need for future co-operation with the United Kingdom. Professor Murgatroyd will visit Venezuela, Colombia, Peru and Mexico from March 30th to April 29th; and Professor Kay, Chile, Argentina, Uruguay and Brazil from March 23rd to April 29th.

C.E.G.B. Heraldry

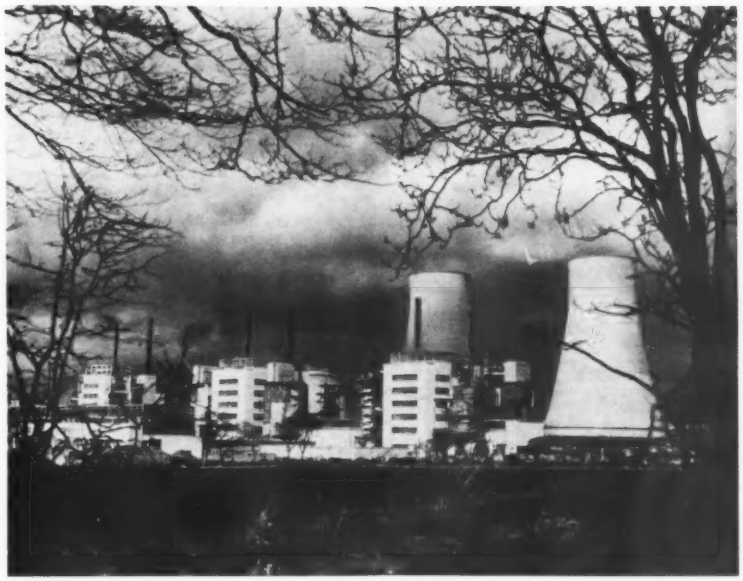
PALY gules and or 2 *bars dancetty the upper per pale sable and argent the lower per pale argent and sable; and for the Crest: On a wreath or, gules and sable a male griffin segreant gules armed langued and rayed or behind the head a sun in splendour gold; and for the Badge: A male griffin segreant gules armed, langued and rayed or behind the head a sun in splendour gold; and for the Supporters: On the dexter side a lion guardant or winged gules on the sinister side a dragon gules winged or.* Thus runs the official description, in heraldic terms, of course, of the recently-approved armorial bearings of the Central Electricity Generating Board. The bearings consist of a coat of arms and crest with supporters and a badge. The first line of the heraldic description refers to the shield. This is divided horizontally by two zigzag strips (" bars dancetty ") which are alternately black and white to represent coal and water. Background of the shield consists of vertical red and gold strips to represent heat. Supporting the shield are on one side a winged lion and on the other a red dragon. These allude to England and Wales, the countries over which the Generating Board's responsibilities extend. The helm and mantling which rest on the shield are surmounted by the crest wreath which is composed of the Board's livery colours, gold, red and black. The crest itself is a male griffin, which as usual is depicted bursting with energy. Heat and power are further symbolized by the flaming sun behind the griffin's head. The griffin will be used as the Board's badge to be worn by uniformed employees. Motto of the Board is " Power in Trust."

Premier Sees Dubna

DURING his recent visit to the Soviet Union, the Prime Minister, Mr. Harold Macmillan, visited the Joint Nuclear Research Institute at Dubna. After a welcome from Dr. Vasily Emelyanov, head of the U.S.S.R. Council of Ministers' Central Atomic Energy Administration, and Dr. D. Blokhintsev, director of the Institute, Mr. Macmillan saw the Institute's 680 MeV synchrocyclotron and 10 GeV proton synchrotron, as well as various research laboratories and the power house.

Be. Plant Planned

PLANS for a plant at Avonmouth for commercial production of nuclear grade beryllium metal have been announced by Imperial Smelting Corporation, the U.K. operating subsidiary of Consolidated Zinc Corporation. The plant is expected to be in operation at the end of this year, and will be the first commercial production unit for virgin beryllium in the U.K. Imperial Smelting Corporation have been under contract for a number of years to the UKAEA, investigating a thermal reduction method. They state that this work has been successfully concluded and beryllium metal of the highest purity has been produced. The AEA, using beryllium for experimental gas-cooled reactors, is the largest user in the U.K.



N-Power Serves Scots Grid

Scotland's first nuclear power station at Chapelcross, near Annan, Dumfriesshire, is now feeding electricity into the national grid. The first of the station's four reactors went critical last November and it completed its testing and commissioning period in February. Steam has been produced for some time and before the completion of the steam circuit and turbo-alternator was fed into a dump condenser. When all four reactors are working the station will have a generating capacity of 184 MW, about 140 MW of which will be fed into the grid. The construction of Chapelcross is under the control of Merz and McLellan, the Consulting Engineers, who are acting as agents for the Atomic Energy Authority's Industrial Group, the first occasion on which a private firm has been employed in this way on a major project. The official opening of the station will take place on May 2nd. The ceremony will be conducted by Col. Sir John Crabbe, OBE, MC, TD, Lord Lieutenant of Dumfriesshire. Among the contractors who have provided equipment and services for the construction of Chapelcross are:—Babcock & Wilcox, Ltd. (heat exchangers), Alex. Findlay & Co., Ltd. (steelwork), Jas. Kilpatrick & Son, Ltd. (electrical installation), Mitchell Construction Co., Ltd. (civil engineering), C. A. Parsons & Co., Ltd. (turbo-alternators), Stewarts & Lloyds, Ltd. (pipework) and Whessoe, Ltd. (pressure vessels)

New Lab. Opened

A LABORATORY devoted to the study of the effect of nuclear weapon debris has been opened by the Reactor Monitoring Centre of Tracerlab, Inc., at Richmond, California. Research in the laboratory, which covers about 1,500 sq.ft of working space and cost $40,000 to build, will be carried out under contract with the New York Operations Office of the U.S. Atomic Energy Commission. Fauna, flora and mineral samples will be collected and analysed for their radioactivity content. In particular, analyses will be made for potentially hazardous radioisotopes.

R.R. Group

VICKERS Ltd., Foster Wheeler Ltd., and Rolls-Royce Ltd., have jointly formed a new company to be known as Rolls-Royce and Associates Ltd. The object of the new company will be the design, development and procurement of nuclear power plants. The parent companies are already associated in Vickers Nuclear Engineering Ltd., and have done considerable work for *H.M.S. Dreadnought*, the Royal Navy's first nuclear-powered submarine. The establishment of the new company formalizes arrangements which already exist between the three companies.

Radiation Protection

BASIC standards for the protection against radiation hazards of the population and workers in the nuclear installations of the six member countries of the European Atomic Energy Community (Euratom) have been published in the *Official Journal of the European Communities*. The standards will serve as a common basis for subsequent legislation in the member countries. The Commission of Euratom has the right to make recommendations which will ensure the harmonization of this legislation if this proves necessary. The draft of the basic standards was drawn up by the Euratom Commission and subsequently approved by the Community's Parliament, its Scientific and Technical Committee, and—finally—its Council of Ministers.

I.A.E.A. Chief Speaks

"SHALL the atomic energy contribution of the technologically advanced and materially endowed nations to other countries in the world be given and applied through truly international channels; or shall we continue to channel such aid through networks of bilateral agreements for selective nation-to-nation exchange without benefit of the balance wheel of international considerations?"..." Shall the peacetime production and utilization of nuclear materials around the world be carried out under international codes and standards for health and safety; or shall we permit the peaceful exploitation of atomic energy under varying, perhaps conflicting, and certainly confusing and only partially effective nationally imposed standards for health and safety?"..." Shall the nations seek in unison to establish and maintain uniform, practical rules to prevent the diversion to military purposes of nuclear materials supplied for peaceful use; or, shall we, dangerously and foolishly, let any and all supplying countries of such nuclear materials make their own rules and apply them as they deem desirable under unpredictable conditions of inter-nation competition?" These questions were asked by Mr. Sterling Cole, director general of the International Atomic Energy Agency, when he recently addressed the ninth annual conference of the American Association for the United Nations. Mr. Cole said that unless these questions were answered positively in favour of the utilization of multilateral agreements and international channels, then the IAEA could hardly accomplish its full purpose. He continued by outlining reasons why this was so. Mr. Cole, who is an American national, flew the 6,000 miles from Vienna, the IAEA headquarters, to New York specially for the occasion.

For Belgian Reactor

THE pressurizer for the BR-3 pressurized water reactor under construction for the Centre d'Etude de l'Energie Nucléaire at Mol, Belgium, has been built at Dunkirk, New York, by the thermal products division of ALCO Products, Inc. Weighing 19 tons, the vessel is clad with stainless steel to resist the corrosive effects of radiation. The function of the pressurizer will be to build up pressure in the reactor's primary system by utilizing heat induced through 90 electrical heater elements. Cost of the pressurizer is more than $60,000. The reactor, which is due to be in operation by 1960, is being built by Westinghouse.

Combatting the "Bulge"

EMPLOYERS are being urged by the British Employers' Confederation to train more young workers during the "bulge" years than will be required to meet their immediately foreseeable requirements. A report prepared by its industrial education and training committee setting out the considerations which lead to this conclusion has been sent to all employers' organizations which are members of the Confederation. Membership covers all the major private industries in the United Kingdom. These organizations are being pressed to take prompt action so that industry will be ready to take full advantage of the situation that in 1961 to 1965 some 35 per cent. more children will on average reach the age of 15 each year than in 1956. According to the 1951 Census there were about 3m. skilled men in England and Wales in occupations to which entry is normally by apprenticeship. The present annual recruitment of apprentices is nearly 100,000 a year. If industry were to take an additional 35,000 apprentices a year for each of the 5 years, without making any allowance for wastage during training it would at the end of that time have added about 175,000 trained men to the total skilled labour force—an addition of about 6 per cent.

Line Change

NEW telephone number of Aveley Electric Ltd., at 15-16, Ayron Road, Aveley Industrial Estate, South Ockendon, Essex, is South Ockendon 3444.

"Good Start Made"

EURATOM offers its members the opportunity and the means, of playing a full part in the great scientific and technical transformation of the world, said M. Etienne Hirsch, newly appointed president of the Euratom Commission, when he took his oath of office recently. It was too early, he said, to draw up a balance sheet of the Atomic Energy Community's achievements after only 12 months of its life. It had had to set up an entirely new organization and recruit suitable staff before beginning on its tasks. Nevertheless, the foundations for its work had now been firmly laid. In order to take the maximum advantage of nuclear discoveries the Community had to train young scientists, encourage wide research, and promote the establishment of nuclear power stations on a scale sufficient to allow the Community's industries to adapt themselves to the new techniques which they required. The prospects open to Euratom had been widened by the agreements it had already signed with the United States and the United Kingdom. There was now the prospect that the resources of the Community's six countries could be harnessed to a common effort for the peaceful application of nuclear power, and associated on equal terms with other nuclear powers elsewhere in the world.

Danish Envoy Tests Controls

The Danish Ambassador tests the emergency shutdown operation of the nuclear instrumentation system developed by Ekco Electronics, Ltd. for the new Danish research reactor DR3

Firm Starts Up

A NEW firm has been established for the manufacture and supply of radiographic equipment and accessories. It is R. F. Fraser-Smith, of 69, Kings Cross Road, London, W.C.1 (telephone: TERminus 1064/5). Enquiries are welcomed on the subject of non-destructive testing and the firm will be glad to supply advice and best prices for appropriate apparatus.

Ultra-Sound Camera

AN ultra-sound camera which enables an image of ultra-sound distribution to be recorded on the camera face was demonstrated at a recent meeting of the electronics and communications section of the Institution of Electrical Engineers. Coupled with acoustic lenses and immersed in a suitable medium the internal structure of substances and objects transparent to ultrasonic waves can be studied with this instrument. In its uses it is complementary to X-ray and ultrasonic pulse-echo inspection methods, and has applications for non-destructive testing in engineering, medicine and other fields. The demonstration was given by Mr. C. N. Smyth, MA, BSc, BCh, and Mr. J. F. Sayers who acknowledged the support given to the building of their instrument by the R. W. Paul Instrument Fund Committee and Northampton College of Advanced Technology.

Preparing a Tender

by

David Welsh

Atomic Power Constructions Ltd.

Hundreds of drawings have to be prepared for a tender for a nuclear power station. When finished they are stored in specially designed folders (below)

One of the nuclear power consortia tendering for the 500 MW nuclear power station to be built for the Central Electricity Generating Board at Trawsfynydd, North Wales, is the Atomic Power Constructions Ltd. This article describes some of the work that has gone into the preparation of their tender, which is their first. Tenders, incidentally, were submitted at the beginning of March and a contract is expected to be announced by June 1st

THE preparation of a tender for a contract worth around £50m. is a major event in the life of any company; for us at Atomic Power Constructions it was all the more so since the Trawsfynydd tender was the end to which the greater part of our efforts have been directed since the company's inception in December, 1956.

The Enquiry Specification laid particular stress upon an easily understood presentation and so at an early stage an editor with journalistic experience was appointed to lay down standards of layout and composition. It was decided, too, that to obtain uniform presentation the printing of all contributions (which were to be received from a wide variety of sources) would be concentrated at our head office in Theobalds Road, London, W.C.

The staff and equipment of the printing department were accordingly built up to a level capable of an output of 15,000 foolscap sheets per hour and 2,500 drawings per day.

About three months before tender date, which was at the beginning of March, the design departments and member companies set about writing the tender document in earnest. The writing of the tender was an operation that involved every department and, to a greater or lesser degree, every individual member of the firm; when it was in full swing it was a job as big as the firm itself. As authors got into their stride, therefore, and the output of written matter and drawings rose it was necessary to decentralize progressively the editorial process.

Editorial Panel

Decentralization was done by setting up an editorial panel with editors responsible for each of the sections (reactor unit, generating plant, electrical equipment, etc.) into which the tender was divided and by further delegating editorial responsibility to assistant editors. The editors and assistant editors were drawn from the design departments originating the material which they were to check, the object being to ensure, so far as possible, that checking was performed by staff technically familiar with the material under review.

After preliminary checking by the assistant editor the original was sent to the printing department where an offset master was prepared by the Xerography process. In this process a special camera is used to obtain an image in the form of electrostatic charges on a selenium-coated aluminium plate. The image is developed by cascading carbon impregnated granules over the plate; these adhere only to the charged areas. The carbon granules are then transferred to the paper offset master by a further electrostatic process and the resulting image is fixed by baking it on to the paper in an oven. Preparing a master by this process takes about five minutes.

Pages for inclusion in the tender document were obtained from the master sheets by offset litho printing on rotary machines. The result of each run, consisting of some tens of copies of a particular page, was placed in a pocket-type folder and transferred to specially erected shelves in the company's strong room.

The next stage in the process was collation; the placing of pages in

proper order in the loose leaf ring binders in which the tender was presented. Between 20 and 40 pocket folders containing consecutive pages were transferred from the vault to a collation team. Here the stack of pages (all identical in any given stack) were laid out in sequence along long trestle tables. The collation team consisting of a dozen or so people circulated in procession round the tables, each member picking up one page from each stack.

The pages sorted into sets in the correct sequence in this way were then loaded into the ring binders. This method has an advantage over the converse one where each member of the collation team circulates round the table with a stack of identical pages; it is that the loading of the ring binders—which is relatively time consuming—can be accomplished at a single operation.

Extra Material

After collation the ring binders were passed to a page checking team. Each member of this team, which numbered about 20, checked the sequence of pages in a single binder from link references called out by the team leader. Link references were used between pages instead of page numbers to allow for the insertion of extra material into the tender as writing progressed.

Reference has already been made to the vault master copy which indicated the state which printing had reached at any given moment. In addition a "collated master copy" was also made available for the inspection of assistant editors and authors. This master copy indicated the stage that collation had reached at any given moment. On the basis of examination of this master and from copies of the printed sheets returned direct to the assistant editors, reprints were made when amendments or additions were needed. The use of Xerography made this a particularly simple process.

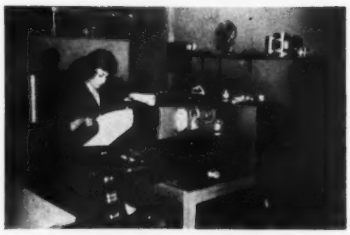
Amendments were made simply by pasting the revised version over the matter to be replaced on a printed copy and treating this as a new original. A distinguishing mark ensured that the latest version of a particular page was the one incorporated in the tender document.

"Double Elephant" Drawings

Complementing the written material in the tender were well over 1,000 drawings of double elephant size. About a third of the tracing work was undertaken at head office, the rest being done either in the member companies or by agencies. Some 18,000 prints were taken off these tracings in the printing department—comfortably within the capacity of the two dye-line copiers with which they are equipped.

Statistics

Finally, a few statistics may point up the magnitude of the task. In the preparation of the tender over five tons of paper were used; 1,250,000 foolscap pages and 18,000 drawings were printed. Ancillary supplies included 12,000 folders and nearly one hundredweight of adhesive paste. The documents, which were contained in 11 standard four-drawer filing cabinets and 45 boxes 3 ft × 4 ft, needed two motor coaches to transport them.



(*Top*) Mr. L. G. Copestake, deputy chief engineer, Mr. J. T. Boddington, Trawsfynydd project engineer, and Mr. A. W. Ashley, chief engineer, at a project conference. (*Centre*) A master copy of each page of the tender is made using the Xerography technique. Pages are then printed from the master on an offset machine. (*Below*) Collation of pages as they come off the offset machine. Twelve copies of the tender are prepared

In retrospect, I think that most of us at APC would agree that, though the work was hard, the sense of urgency and purpose in tendering for Trawsfynydd was not without its compensations.

Everything is meticulously checked

Drawings are printed on a dyeline machine

BUILDING THE REACTOR

by A. L. BRAKE, A.M.I.Struct.E.

The author, who is civil engineering project engineer for the Berkeley nuclear power station, describes the building of the foundations, the pressure vessel, biological shielding, the superstructure and boilers at Berkeley. This is the second of a series of articles based on lectures recently given at the South East London Technical College. Next month, Mr. W. A. Gillingham, of W. S. Atkins and Partners, will write about the active drainage at Berkeley

1. The Foundation

THE radial layout of the Berkeley reactor CO_2 gas ducts and the decision of the contractors, AEI-John Thompson Nuclear Energy Co. Ltd., to erect the boilers "Calder" fashion by means of "gin-poles" has resulted in the blowers and boilers for each reactor being located some distance from the pressure vessel. The intensity of loading under the pressure vessel and biological shield is high, whereas under the blowers and boilers it is considerably lower. Following a favourable soil mechanics report which indicated that settlement would not be significant, it was decided to take advantage of the small differential settlement allowances made available by the plant engineers and support the pressure vessel, the biological shield and the reactor building on an inner circular raft and support the blower house and boilers on an outer ring raft.

The Centre Raft

For design purposes the centre raft was considered to be a circular plate fixed to and enclosing the bottom of the cylindrical biological shield and adjustments were made in the design to cater for its irregular, serrated edge. The outer ring raft under the blower house is an extension of the blower house retaining wall footing and is loaded with about 12 ft of mass concrete to provide stability under all possible conditions of external water pressure. The blower pits are located in this mass concrete and the retaining wall is carried around the boiler pits. This wall and its extended footing which forms the ring raft make up the watertight structure which embraces the blower house basement.

The inner edge of this ring raft is constructed to the bottom lift of the main control raft by means of a 2 in. rubber water bar to allow for minor differential settlement. Mass concrete bases under the boiler pits spread the relatively heavy loading from the boilers.

51,000 ton Loading

For the centre raft normal tensile and compressive stresses were allowed in the reinforcement and in the concrete but the shear stress in the concrete was limited to 60 lb/sq.in. due to the method of placing the concrete in lifts. A minimum cross sectional area of shrinkage reinforcement of 0.2 per cent. per exposed face was allowed. The loading on the centre raft from the reactor building, biological shield, pressure vessel and concrete plus the self weight of the raft amounts to about 51,000 tons, resulting in a gross average bearing pressure on the formation of 2.86 tons/sq.ft.

The raft is stepped to spread the load from the pressure vessel and biological shield and the bottom lift which is 2 ft thick contains all the tensile reinforcement. For construction purposes this lift was divided into 13 sections, the largest being 40 ft square.

Construction joints and reinforcement layout were carefully planned so that all stop-ends should cross the reinforcement at right angles. The concrete placing sequence was also carefully planned to give the largest possible interval between the concreting of adjacent bays. The complete operation of placing the bottom lift concrete took 12 days.

Bases for the monotower construction cranes were cast up against this bottom lift separated by a rubber water bar which also runs around the bases themselves, isolating them from the outer ring raft. Succeeding lifts are 3 ft thick, construction joints being staggered. The raft thickness around the perimeter at the bottom of the stepping is 11 ft (i.e., bottom 2 ft lift plus 3 × 3 ft lifts, the bottom 2 ft lift also forming the floor of the CO_2 duct pits) and the thickness in the centre is 14 ft (i.e., bottom 2 ft lift plus 4 × 3 ft lifts).

Lifts 2 and 3 and the stepping and the plinths supporting the pressure vessel sill beam all contain spun concrete pipes 2 ft 6 in. deep × 4 ft diameter to lighten the raft and to help break up the mass of concrete and prevent heat build-up during setting. The lifts contain shrinkage reinforcement only in the top face and this was laid on top of the expanded metal which covers the top of the pipes 6 in. from the lift surface.

Thermocouples Included

Among special items built into the raft are intake and extract ducting to the bottom air-cooling circuit and vault cooling and an R.S.J. grillage, set on top of the raft in the centre to carry the mild steel thermal shield plates and to provide the interspace for air cooling. Special fixings are also built into the walls of the pressure vessel support plinths and the top of the sill beam to carry the thermal plates and the bed plates which provide the bearing for the pressure vessel legs. Thermocouples for recording operating temperatures in the concrete are also built into the construction.

Above lift 5, concreting by lifts was discontinued and the plinths and the sill beam were constructed as single operations. The top of the sill beam can be considered as the

demarcation between the raft conconstruction and biological shield construction.

At this stage of construction John Thompsons were able to start work on the " gasholder," the steel structure supported off the sill beam which provided the controlled working conditions for the welding of the pressure vessel and at the same time, acted as permanent shuttering to the inner face of the biological shield.

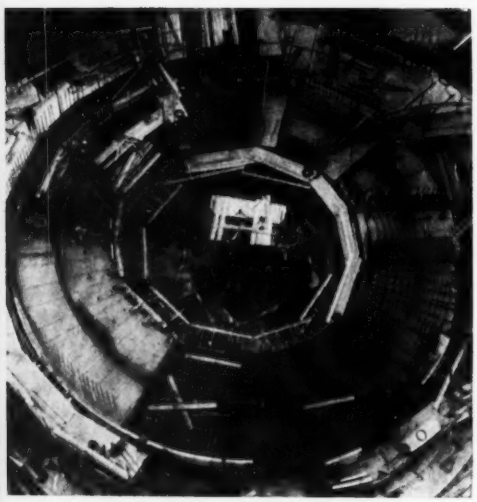
Meanwhile, Laings switched their efforts to the bottom secondary shield. At the same time as work was proceeding on the bottom lift of the centre raft, work was also proceeding on the outermost sections of the ring raft (i.e., the retaining wall footing). This enabled work on the blower house retaining wall to get under way.

Made Water Tight

As for the main raft, so for the outer raft, the layout of the reinforcement and construction joints was very carefully considered, concreting of the sections being carried out on the " alternate-bay " principle to give the longest possible time for shrinkage to take place between adjacent bays. All shrinkage steel was run through the construction joints and the aggregate was exposed on these joints by means of wet-brushing or bush-hammering.

Complete water-tightness is a requirement for the reactor building therefore special attention was also paid to the concreting of the blower house basement retaining walls. Three

Reinforcement of sill beam



July, 1957

September, 1957

Views of raft construction

walls which were about 30 ft high were constructed in two lifts only, each lift being sheltered and cast in one single operation for each section between adjacent boiler pits. The connection to the massive boiler pit buttresses is effected by means of a mechanical shear bay and vertical rubber water bar and the shrinkage between these connections was taken care of by the introduction of a system of vertical rubber duct tubes 6 in. in diameter at third points supported in the shuttering. These were inflated during construction and after the concrete had set they were deflated and withdrawn. The shrinkage then all took place between these deliberately formed planes of weakness and cracks appeared in the thin sections of wall between the holes formed by the duct tubes. Subsequently, the holes were grouted, the cracks sealed and the wall rendered completely watertight.

2. The Pressure Vessel and the Biological Shield

The Calder Hall pressure vessels are vertical cylindrical vessels built of 2 in. thick steel plate. At the time of their construction they were probably the largest pressure vessels anywhere in the world. Since Calder Hall was constructed design improvements have resulted in greater working pressures and the Berkeley pressure vessels (also vertical and cylindrical), designed to withstand a pressure of 125 lb/sq.in. together with the various thermal and loading forms are constructed of 3 in. thick plate. Thus work on the first Berkeley vessel was carried out without previous experience of Class 1 welding on a vessel of this size in the field, with the attendant complex inspection procedure involving magnetic crack detection and X-rays followed by stress-relieving and pressure testing of the complete vessel.

Joints to be welded were preheated to 100°C. Welds were built up, two or three layers on one side, then chipped out at the back and two or three layers built up on the reverse side. Magnetic crack detection was then carried out and the runs to complete the weld were built up, back and front either alternately or simultaneously.

Completed welds were dressed smooth by grinding and X-rayed at

night. Welding procedure throughout was carefully controlled so as to ensure uniform metal shrinkage.

When a vessel is complete it is lagged and a 2 MW electric heater is placed inside to build up a temperature of 650°C. for stress relieving. This temperature is held for 4hr. The completed vessel is also pneumatically pressure tested. The test pressure will be 162 lb/sq.in.

Each pressure vessel at Berkeley is supported on 18 rolling supports which carry the load from the wall of the cylinder to the sill beam that is built up as part of the main biological shield. Loads taken by the sill beam are transferred to the raft by means of the plinths between which pass the bottom CO_2 gas ducts.

Like Colander

The top of each pressure vessel is rather like a kitchen colander, it being pierced with a series of holes designed to take the control rods and fuel chutes. Provision has to be made in the top shield for the displacement of these tubes due to the temperature changes that will occur during reactor operation.

As the hand-over date for Reactor No. 2 is six months behind No. 1, it was possible to arrange the construction programme so that the entire pressure vessel for No. 2 could be built *in situ* on the raft. Only on No. 1 was it necessary to construct the pressure vessel bottom dome off the raft and at the same time as the latter.

The pressure vessel and shield construction for reactor No. 1 can be sub-divided as follows:—

Operation 1.

The main foundation raft and pressure vessel bottom dome were built simultaneously.

Operation 2.

The bottom secondary shield and the bottom section of the "gasholder" were built simultaneously.

The horizontal slab of the secondary shield was required to support the working scaffold for the main shield construction. Only two thirds of the bottom section of the gasholder could be built at this stage, an entrance being required for running in the pressure vessel bottom dome.

Operation 3.

The pressure vessel bottom dome was run into position.

Insertions in the biological shield

Operation 4.

The " gasholder " was closed, the lid put on and work proceeded inside on the pressure vessel barrel and outside on the biological shield up to the seating level of the top CO_2 duct sleeve supports, a chase being left for the top secondary shield and various slabs and beams on the way. Curved, climbing shutters were used for the outside of the shield. Lifts proceeded approximately 3 ft at a time. Horizontal joints were prepared by hosing and brushing to expose the aggregate on the surface and were thoroughly cleaned off with compressed air.

Mock-Up Made

In this section of the barrel are situated the ion chamber tube assembly. This is an assembly of 10 tubes stepped from 6 in. to 8 in. diameter passing through the shield and concentrated in an area roughly 6 ft × 4 ft. It was essential that the concrete around these tubes should be of uniform density and completely free from honeycombing. A " mock-up " was made on site therefore and concreted and broken-up and examined in order that everyone concerned should be assured that the desired results could be achieved.

When a further ring of barrel plates was required for the vessel the temporary lid was lifted off the " gasholder " by one of the two 15 ton monotower cranes and then the same cranes lowered the plates into position and re-placed the lid.

Operation 5.

The "gasholder," was extended, the sleeves for the top CO_2 ducts were set on the top of the portion of the shield cast and welded to the " gasholder " and the necessary opening cut therein. The horizontal slab of the top secondary shield was cast with a flexible joint to the main shield.

Operation 6.

Work was continued on the main shield up to the seating for the top girders and beyond into the shrouds which will shield the top CO_2 ducts from the charge face operators.

Operation 7.

The lid was removed and the top dome plates lowered in on to a jig. The top shield plate girders were lowered into position by the monotowers and the " gasholder " lid was placed in its final position on top of the shrouds. The top dome was completed and the grid of girders was used as a platform for the

accurate marking out of the numerous holes which were cut therein and for the subsequent welding on of the stubs.

Operation 8.

This will be the setting-up of the top thermal shield on the bottom flanges of the plate girders and the concreting by stages of the biological shield cap.

This biological shield cap is of composite construction employing steel plate girders of normal reinforced concrete and is designed to be entirely self-supporting during all stages of construction. During the construction of the " ring-beam " or outer-ring of the cap, the plate girders act as simply supported beams spanning between the barrel of the shield. However, on completion of the " ring-beam " a more complex structure results in which the ends of the girders are restrained. On completion of the " central disc " up to the underside of the layer of iron shot concrete a further change in section takes place and for all loads applied after this stage a composite section is considered where all the compressive stresses are taken by the concrete and the tensile stresses at mid-span by the plate girders.

Constructed around the main biological shielding is the secondary shielding the purpose of which is to shield the openings through the main shield and also to shield the CO_2 duct, etc., emerging from these openings.

Installation of Plant

The walls of the bottom secondary shield are at present open for the purpose of installing plant. Half of the openings will be filled with *in situ* concrete, half with pre-cast blocks in order to give access for maintenance purposes. There are also shielded man-access holes to the pressure vessel vault.

3. The Superstructure and Boilers

The walls of the top secondary shield form part of the external wall of the reactor building. The main columns are grooved, pre-cast cladding panels were dropped in, shutters fixed to the backs of the columns and the shielding poured *in situ*. Between the top and bottom secondary shields these panels are used without backing as the main cladding.

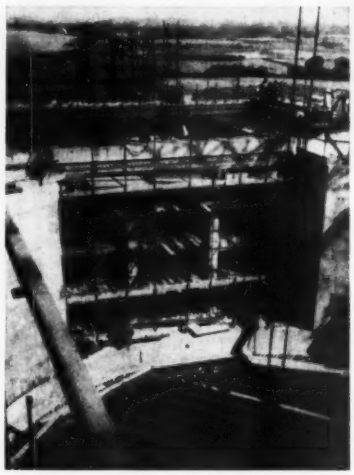
Notable steelwork items are:—

(*a*) The pin-based portal frame structure of the charge face building which is supported off the top of the shrouds.

(*b*) The annular pin-based portal framed structure of the blower house on which run the annular electric overhead cranes.

(*Right*) **Reinforcement around ion chamber**

(*Below*) **Main girders to top shield**



The boiler shells are assembled on site from pre-fabricated rings made of $1\frac{1}{8}$ in. thick steel plate. Each shell is made of five cylindrical rings and a domed top and bottom section plus a support skirt.

The boilers are towed from the site shop to the reactor in the horizontal position and then lifted into their vertical position over the boiler pit by means of the gin-poles and winches.

After each boiler has been erected a steel framed boiler structure is built around it. The boiler is then fitted out with its h.p. and l.p. drums, etc., the boiler structure is clad and a " clean conditions " hut is erected on the top of the boiler so that the tubing out can proceed under scrupulously clean and controlled conditions.

The civil engineering work on Reactor No. 1 is now nearing completion.

Mostly Conventional

A great deal of this work is purely conventional in form but the " in-line " programme for major plant installation called for some unconventional construction methods.

However, at Berkeley, the unconventional approach has only been adopted after a thorough investigation into both feasibility and economics.

An example of an unconventional idea which was taken up is the " gasholder." An effective and cheap solution to the problem of the simultaneous construction of the pressure vessel and shield.

On the other hand it was decided that the most economic and practical form of crane to serve this construction would be 15 ton monotowers and these cranes are entirely standard and conventional. They have proved to be the most flexible and versatile of tools and have been continuously in operation for both plant and civil contractor.

The design of the Mark II reactors for the proposed station at Trawsfynydd in North Wales is more compact and the constructional problems will be different, calling for different solutions and different cranage. However, the same yardstick will be applied as for Berkeley and it is quite certain that Trawsfynydd could be conquered without bringing a " Goliath " to the " Land of David."

Acknowledgements

Acknowledgements for permission to produce this article are made to the principal of the South East London Technical College, Central Electricity Generating Board, AEI-John Thompson Nuclear Energy Co., Ltd., and W. S. Atkins and Partners. Photographs are supplied by John Laing & Son Ltd.

DRAGON

INTERNATIONAL REACTOR PROJECT

DRAGON, the five-year project in which 12 countries are to jointly investigate the use of high temperature gas cooled reactors for nuclear power stations and other applications, will be centred on a 10 MW reactor to be built at the UKAEA Research Establishment at Winfrith Heath, Dorset. This article describes a possible design for the reactor.

IN order to investigate the problems of high-temperature gas-cooled reactors, it is desirable to build and operate a reactor experiment which will incorporate most of the characteristics of a possible power unit. A preliminary design study of a 10 MW reactor experiment has been carried out at Harwell and further extensions to this work with the possibility of building such a system, are under consideration.

A general arrangement of the reactor, as envisaged during the preliminary design study, is shown in Fig. 1 and although further work on design detail will certainly involve many modifications, the drawing serves to illustrate the basic principles which would underly the final design.

The fuel elements in this system are constructed from graphite, uranium-235, and thorium. Each fuel element consists of seven closely packed rods, united to form a hexagonal array, as illustrated in Fig. 2. Each fuel-rod has a sheath of graphite on the outside and a mixture of moderator, fissile and fertile materials inside the sheath.

In the design illustrated in the figure, the mixture forms an annular fuel insert around a central graphite spine, but alternatively it could be in the form of a solid rod within the sheath. Each fuel-rod contains at its upper end an inlet vent containing a porous plug through which a bleed flow of coolant gas passes, while at the bottom each of the seven rods is vented into a common duct in the block which holds them together and which seats on to a hollow

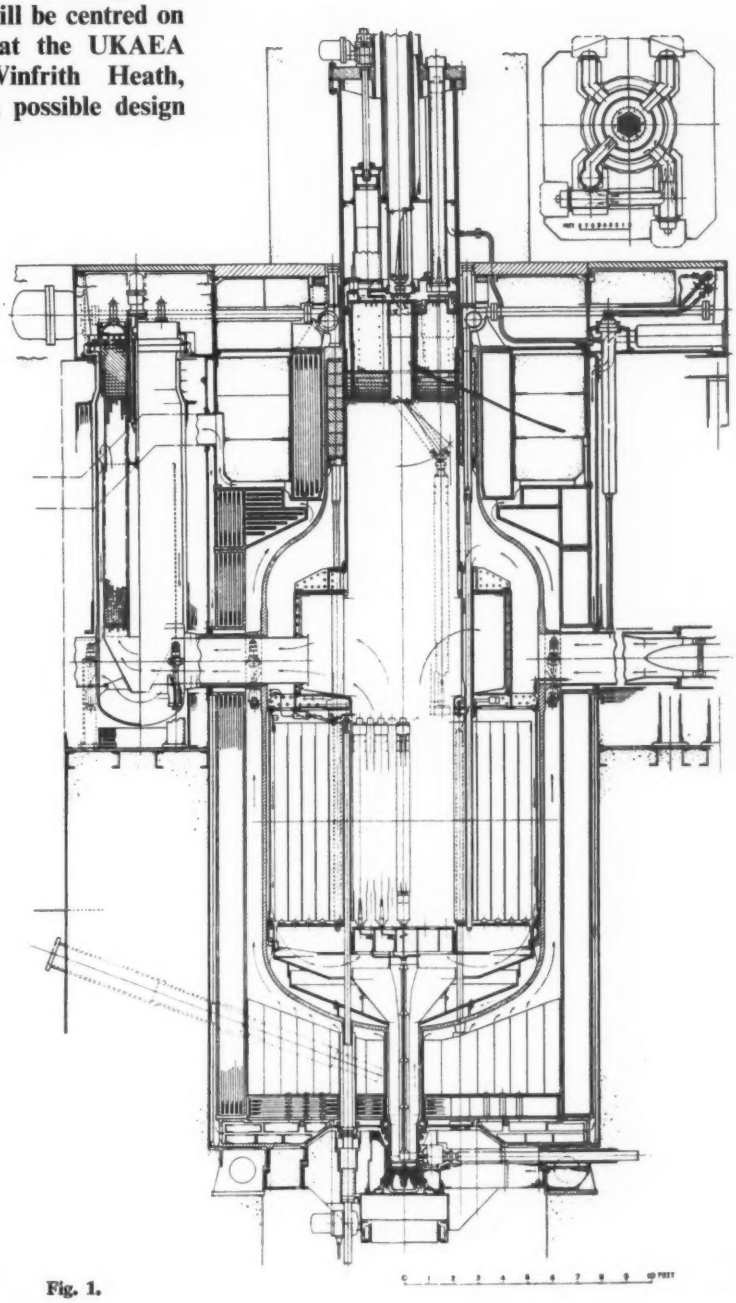


Fig. 1.

mounting spike through which fission products are extracted.

Each fuel element is 8 ft (approximately 2.4m) long and the individual rods, each a little over 6 ft long, are sealed to the bottom block and retained with metal bolts. At the upper end, the rods are joined to a spider shaped block by metal capbolts and diaphragm washers to accommodate any unequal growth or expansion.

An appreciable length change in an individual rod will not induce serious resisting forces since the diaphragm mounting washers will readily yield at the working temperature. The top block is shaped to position neighbouring elements and a lifting extension is provided for handling.

61 Fuel Elements

Sixty-one of the seven-rod fuel elements make up the core of the reactor, the actual core geometry being roughly a cylinder of 4 ft length and diameter. The closely packed rods have surfaces shaped to define a number of passages through which the coolant passes, the total voidage in the core due to these being approximately 13 per cent. of the total core volume.

The fuel elements, of course, make up not only the 4 ft length of core but also the end reflectors, roughly 2 ft thick at each end. Around the assembled fuel elements is a side reflector made up of graphite columns 8 ft in height with an overall diameter of 10½ ft. About 5 per cent. coolant voidage is provided in this side graphite.

Countries participating in project DRAGON, which was initiated by the OEEC European Nuclear Energy Agency, are Austria, Belgium, Denmark, France, Italy, Luxemburg, the Netherlands, Norway, Sweden, Switzerland, the United Kingdom and West Germany. Estimated cost of the project is £13.6m., £10m. of which will be shared between the participating countries and the rest borne by the United Kingdom, which will retain ownership of the reactor and other installations in England at the end of the project.

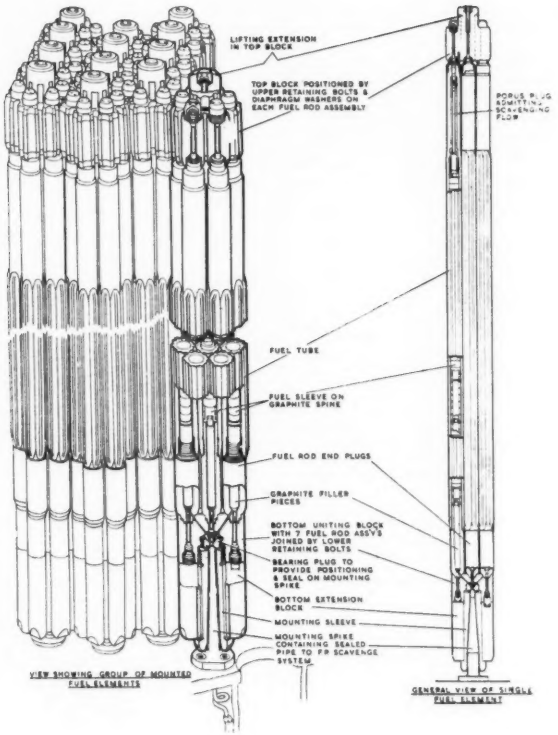

LIFTING EXTENSION IN TOP BLOCK
TOP BLOCK POSITIONED BY UPPER RETAINING BOLTS & DIAPHRAGM WASHERS ON EACH FUEL ROD ASSEMBLY
FUEL TUBE
FUEL SLEEVE ON GRAPHITE SPIKE
FUEL ROD END PLUGS
GRAPHITE FILLER PIECES
BOTTOM UNITING BLOCK WITH 7 FUEL ROD ASSYS JOINED BY LOWER RETAINING BOLTS
BEARING PLUG TO PROVIDE POSITIONING & SEAL ON MOUNTING SPIKE
BOTTOM EXTENSION BLOCK
MOUNTING SLEEVE
MOUNTING SPIKE CONTAINING SEALED PIPE TO FP SCAVENGE SYSTEM
VIEW SHOWING GROUP OF MOUNTED FUEL ELEMENTS
GENERAL VIEW OF SINGLE FUEL ELEMENT

Fig. 2

Both the reflector columns and core elements stand vertically and are pivotally mounted on steel structural members inside a steel pressure vessel, the reflector being arranged to close on to the core to provide an expandable restraint at the top of the fuel-elements.

Helium is Coolant

For a 10 MW output the coolant is helium, at 10 atm. pressure, which enters and leaves by ducts near the top of the pressure vessel. The incoming coolant flows downward and maintains the inside of the pressure vessel and the bulk of the side reflector at a temperature not greatly different from the gas at 350°C. It subsequently flows upward through the core from which it emerges into a nimonic chamber at a mixed mean temperature of 750°C.

The outflowing gas is transferred through a nimonic lined duct to the primary heat exchanger which is water cooled in the arrangement illustrated. It should be noted that the nimonic chambers and ducts are externally cooled by the incoming coolant and they have no structural function. No part of the primary circuit which has to withstand the full coolant working pressure is normally exposed to gas at more than 350°C.

Secondary cooling water emerges from the primary heat exchanger at a relatively low temperature, i.e., about 75°C., so that no excessive pressurization is required and a heat exchanger of small dimensions results from the large temperature difference between the hot gas and the cooling water. Other possible alternative arrangements using an intermediate heat transfer fluid to avoid any possibility of water leakage into the main circuit might be considered. No attempt to generate steam and power is contemplated in this study.

A feature in the primary cooling circuit is the proposal to avoid shaft seals and to use instead completely enclosed motors and compressors with gas bearings. It was not anticipated that a free running gas turbine circulator would be developed in time to be used in this reactor experiment and the required pumping power, of the order of 100 kW, is so low that it would not provide a particularly useful exercise for the principle.

The inset view in Fig. 1 shows a single circuit with two circulators in

series, an arrangement which avoids control valves. However, alternative systems using parallel circuits are worth further consideration and a number of possible circulator and heat exchanger layouts should be examined, before a final choice is made.

Control of the reactor is exercised by means of a curtain of absorbing rods, 30 in number, moving in vertical channels near to the inside boundary of the reflector. These provide a small negative reactivity for shut-down and their removal compensates for temperature coefficient, poison and depletion, a total range of reactivity between 14 per cent. and 15 per cent. being controlled. The possibility of using boron as a burnable poison in the fuel-inserts as a means of reducing the depletion compensation required from the control rods is also considered.

It is proposed that the control rods would be actuated by cable drives with the provision of magnetic clutches in the winding mechanisms to release the cables in the event of an emergency shut-down requirement. In order to protect the actuators from any primary circuit activity, zirconium sleeves are provided which isolate these control mechanisms from the circuit gas and thereby simplify maintenance.

Gas Lock Necessary

In a reactor of this type it is important that one should be able to load and unload fuel-elements without disturbing the helium coolant in the primary circuit. Accordingly a charge/discharge machine capable of transferring elements through a gas lock is required.

The relative infrequency of fuel charging would enable the work to be carried out at a convenient shut-down period when gas temperatures are low and pressure correspondingly reduced. During reactor operation the charge/discharge machine would be parked in a shielded position where the temperature is kept low by a cooled by-pass of gas which subsequently flows back into the reactor.

The fission products pumped from the bottom of the fuel-elements are passed through a fission product trapping system based on the use of active charcoal absorption beds. The emergent helium will still contain the longest period krypton and xenon activities since these are merely delayed. This gas will also go through a chemical purifier to remove O_2, CO_2, CO and H_2O before returning to the main cooling circuit. It is anticipated that the main problem which will be encountered in the reactor experiment will devolve around the effectiveness of the traps and chemical purifiers.

Some Dangers

If the oxidizing impurities in the primary circuit cannot be maintained in the region of a few parts per million, then the amount of mass transfer of carbon with unprotected fuel elements may cause embarrassment. Again, excessive radioactivity would set very stringent requirements on the leak tightness of the primary gas circuits which might be extremely difficult to meet. The engineering will in any case involve successive stages of enclosure with monitoring of interspaces and controlled handling of any leakage.

All joints will be permanently welded or seal welded and any penetrations through the vessel, such as load machine drives, will require several stages of sealing, finally backed by sealed capping enclosures. These will, in all cases, be at cool and accessible parts of the system. The design must also cater for a carefully controlled removal procedure with adequate shielding and sealing for any active member which could require replacement.

This article is based on extracts from a paper presented at the 2nd International Conference on the Peaceful Uses of Atomic Energy.

Research and Development Work Planned

(i) The development of the fuel element graphite (or beryllia) sheaths in impermeable forms.
(ii) The fabrication of high-temperature gas-cooled reactor fuel elements from graphite and beryllia incorporating fissile and fertile materials.
(iii) The behaviour of the fuel elements and core materials under reactor conditions and changes in mechanical and thermal properties resulting from irradiation.
(iv) The mechanical properties of the large fuel element assemblies proposed for the reactor experiment.
(v) Methods of processing the ceramic fuel inserts after their irradiation.
(vi) The compatibility of the coolant gas with the fuel elements, at high surface temperatures and resulting mass transfer problems. The influence of radiation in this connection.
(vii) The emission of fission products from the fuel inserts, at high temperatures, and their diffusion through the materials of the fuel elements.
(viii) The development of an efficient fission product trapping system to remove the volatile and particulate activities from the coolant and to delay active noble gases.
(ix) The chemical purification of the coolant gases to reduce to acceptable levels those impurities which might cause corrosion and mass transfer.
(x) The selection of appropriate structural steels for the primary circuit and the investigation of the behaviour of these materials under the expected temperature and irradiation conditions.
(xi) The examination of the behaviour of special metals, such as zirconium, which might be used in high temperature and high neutron flux regions of the reactor particularly with respect to compatibility.
(xii) The development of totally enclosed circulating machinery with gas bearings; the behaviour of these gas bearings in helium atmospheres and possible action of coolant-borne carbon and fission product particles.
(xiii) Theoretical and experimental studies of fluid flow and heat transfer problems in the core and other regions of the primary coolant circuit.
(xiv) The problems of sealing the primary circuit to prevent the escape of fission products. A high standard of leak tightness comparable to that demanded in high vacuum techniques will be required.
(xv) Methods of processing large volumes of air from the containment vessels or reactor building to remove traces of escaping fission products which might otherwise be released into the atmosphere. This is primarily a question of removing radio-iodine from the effluent air.
(xvi) Development of efficient nuclear-radiation shields capable of retaining their properties at temperatures up to 300°C. or 400°C.
(xvii) Theoretical studies of nuclear physics aspects, kinetics and control problems.
(xviii) Experimental zero energy and exponential studies of the nuclear physics, kinetics and control problems.
(xix) Development of methods of measurement and instrumentation for high temperature conditions.
(xx) Development of certain high-temperature techniques such as the joining of graphite to graphite and the introduction of probes and instruments into very high temperature regions of the reactor.

Engineering, Marine, Welding and Nuclear Energy EXHIBITION

Over 500 firms have booked space at this year's exhibition, which will occupy over 250,000 sq.ft in the three halls at Olympia. This is the second year that nuclear energy has been included as a major feature of the exhibition and it is appropriate that the opening ceremony on April 16th will be performed by Sir Edward Thompson, honorary president of the exhibition and chairman of John Thompson Ltd. This preview covers some of the exhibits most likely to be of interest to visitors from the nuclear field

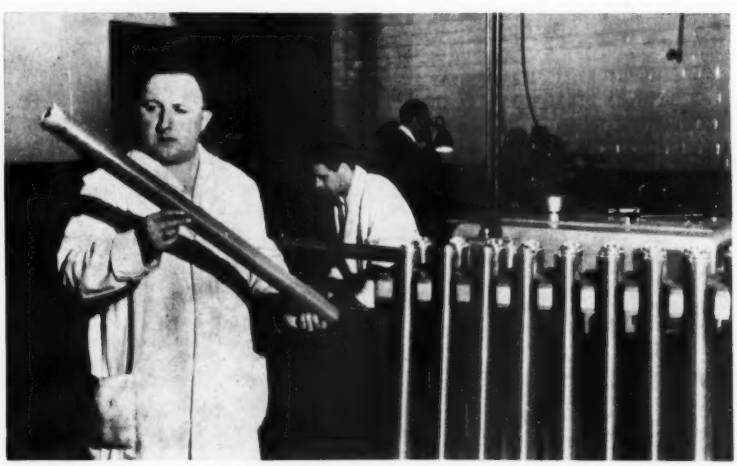
APRIL 16th—30th
OLYMPIA
LONDON

Precision tubes for the nuclear power field will be the main theme at the **Accles & Pollock Stand (50IG),** where a particularly interesting exhibit will be a standpipe head made for use by the General Electric Co., Ltd., in the Hunterston station. The head contains the stainless steel burst cartridge detection tubes which pass through the wall of the pressure vessel standpipe to a rotary selector valve, and is a fine example of precision tube manipulation. Other exhibits on the Accles & Pollock stand illustrating the latest developments in the nuclear power field, include extruded cans in magnox, and tubes in niobium, vanadium, tantalum, zirconium, and titanium and its alloys. Many of the new developments being applied in nuclear power stations will also have a much wider interest for engineers in other fields. These include tubes with extremely thin walls, in stainless steels and other metals, and the convoluted flexible tubing and bellows made from such stainless thin-wall tubes.

Featured on **The Anti-Attrition Metal Co., Ltd., Stand (35OG)** will be "Anti-Attrition" bronzes and whitemetals, as used in all branches of mechanical and electrical engineering, by government departments; British, colonial and foreign railways, transport undertakings, and machine tool makers. A wide range of bearings, lined and unlined, including armature and suspension bearings for locomotives. Non-ferrous sand, die, shell-moulded and centrifugal castings, for oil refineries and chemical plants. Chill and spun cast sticks, 8 in. semi-machined bushings; aluminium, sand and die castings, electric current distribution and collection devices for cranes, etc., and patented magnetic caps for fuel tanks and other containers will be shown.

Exhibits on the **Armstrong Siddeley Motors Ltd., Stand (11J),** can be divided into three groups—Armstrong Siddeley Maybach MD Type diesel engines, re-circulating ball screws and splines and gas bearings. Among the engines will be the MD 330—six cylinder in-line engine, turbo charged, intercooled and capable of developing up to 720 h.p. at 1,600 rev/min, the MD 650—12 cylinder engine of Vee formation, turbo charged with a power output of up to 1,152 h.p. at 1,500 rev/min, and the MD 871/30—16 cylinder engine of Vee formation, turbo charged, intercooled and develops up to 2,880 h.p. at 1,800 rev/min. A recirculating ball screw 40 in. long with a pitch circle diameter of 1½ in. produced for machine tool application will be shown. It will be representative of a comprehensive range of high precision recirculating ball screws and splines manufactured by Armstrong Siddeley by agreement with Beaver Precision Products Inc., U.S.A., for many applications in all spheres of the engineering industry. Features include high efficiency, complete elimination of back lash, long life, low maintenance factor and up to 80 per cent. reduction in the power required for actuation as compared with conventional screw threads and splines. Furthermore, they possess an inherent ability to run at high temperatures without lubrication. In the last group there will be models of gas bearing machines showing the major components of compressors and pumps being developed by Armstrong Siddeley. These are intended to overcome the disadvantages of oil lubricated bearings where support for rotating shafts is required in applications where contamination due to leakage of lubricant cannot be tolerated and in nuclear power plant where bearings, once installed, are inaccessible.

The display being presented by **Sir W. G. Armstrong Whitworth Aircraft Ltd., (45IG),** has been designed specially to focus attention on the large range of engineering facilities and techniques which the company offers to industry. AWA holds several large contracts, each of which presented some new problem that had to be solved before economic flow production was possible. The problems were overcome by the equipment developed by the company's process development department, and the work is now in full production at most competitive prices. For instance, at the exhibition there is an example of the fuel "cans" of the Calder Hall type which the company manufacture for the United Kingdom Atomic Energy Authority. These illustrate machining from solid bar to very fine limits. The continual-spiral fin on the cans is machined in one operation by a method developed by the company. Another exhibit shows the stretch forming of heavy extrusions, which have been performed on a Hufford A.46 stretch-form press. Much development work on fibre glass moulding has been done at the company's Baginton factory during the past few years, and examples of ducting, battery boxes and fairings of many shapes and sizes will be shown, together with a large variety of



Nuclear energy fuel cans machined from solid light alloy bar at the Sir W. G. Armstrong Whitworth Aircraft Ltd. works. Samples will be displayed on Stand 45 IG

injection and pressure mouldings in nylon, polythene, fluon, etc. Also on show will be three examples of the electronic equipment produced by AWA. The first is five-channel cathode ray tube recording equipment, complete with camera. The second, a working display showing sampling techniques applied to industrial instrumentation; and the third item, is a sweep oscillator and vibration controller for environmental or dynamic testing.

A representative selection of Auto-Klean self-cleaning filters supplied in capacities up to 400,000 gal/hr for almost every liquid used in modern engineering is to be shown by **Auto-Klean Strainers Ltd., (3D).** The working principles of Auto-Klean filters will be demonstrated and the types shown will illustrate self-cleaning filters for service in a variety of marine and industrial applications. A special feature will be the new Auto-Klean Micom filter, which represents an important development in filtration for closed-circuit lubricating oil systems in many branches of engineering. Recent Auto-Klean developments in fine-mesh self-cleaning filters and magnetic filters for large engines are on display and, in addition, a new range of Auto-Klean self-cleaning filters designs with greatly improved flow characteristics will be displayed.

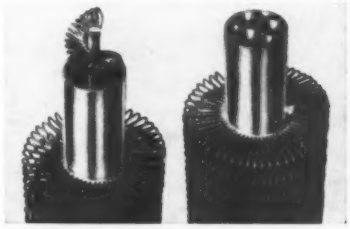
A wide range is shown of " Lascar " jointings, packings, asbestos, and mechanical rubber goods, for marine and industrial services will be shown by **Beldam Asbestos Co., Ltd., (3D).** Jointings include " Asoid " for universal service," Kymbala " for superheated steam, " Lascaroilite " for oils and distillates, a selection of rubber jointings, and new developments in the field of jointings treated with polytetrafluoroethylene for corrosive fluids. A special feature will be made of ready-cut joints in various sizes and " Lascarflex " spirally wound gaskets. The range of packings displayed will cover a wide field of engineering services and include specially developed packings for the oil and chemical industries, tank-lid packings, and stern-gland packings.

Exemplifying a new series in the well-known range of Birlec mesh-belt conveyor continuous furnaces for annealing and brazing, the centre-piece of the **Birlec Ltd., (13E) stand**—a hump-back furnace—shows several interesting features. Rated at 20 kW and with a conveyor belt 6 in. wide to carry the work continuously through the treatment process, this furnace has been developed for the bright annealing and brazing of a wide range of components in stainless steel and similar materials. An essential requirement for the treatment of stainless and heat resisting alloys is a protective atmosphere of utmost purity. Either hydrogen or a hydrogen-nitrogen mixture derived from ammonia is the atmosphere gas generally used. To prevent contamination and to reduce the gas consumption to a minimum, the furnace is provided with a continuous, internal gas-tight muffle with sloping inlet and outlet tunnels. The heating chamber is fitted with silicon carbide elements which are easily removable and which enable working temperatures up to 1,200 C. to be attained. The conveyor belt, of woven nickel chromium wire mesh, is driven by a special system which ensures a minimum tensile stress in the heated portion of the belt, thus prolonging its life. For exhibition purposes, the furnace will be equipped with a standard Birlec exothermic atmosphere generator of a recent and simplified design suitable for the smaller range of furnaces. The atmosphere provided by this equipment is suitable for the bright normalizing and copper brazing of mild steel and the annealing of many non-ferrous metals. It is generated from ordinary town's gas or liquid petroleum gas by combustion with air: the proportions can be closely adjusted to give an appropriate atmosphere composition. The application of Birlec dryers to factory compressed air systems will also be illustrated and there will be a model of the Birlec sealed quench furnace on show. This will be arranged to illustrate an automatic operating cycle under timed sequence control. This type of furnace, widely used by the automotive and other engineering industries, is designed for gas carburizing, carbonitriding, clean hardening and carbon restoration processes.

Photographs of nuclear power station sites will be featured by **Butters Bros. & Co., Ltd. (2L),** to show their cranes in use. One of them will be a 10 ft × 5 ft blow-up of an aerial photograph taken at Berkeley where four 15 ton Butters Monotowers are working. A working model derrick crane will also be on show on the stand.

Graphic demonstration of the salient characteristic of amosite asbestos, its " flocculence " (bulkiness when fibreized) will be given on the stand of **The Cape Asbestos Co., Ltd., (13AA).** A small piece of crude amosite from the company's own asbestos mines in South Africa—Cape are the world's largest producers of amosite—will be shown alongside a massed pile representing the same weight of crude when fibreized. A new colour sound film showing how crude asbestos is extracted from rock inside one of the Cape Asbestos mines in South Africa will be shown publicly for the first time. Also featured will be the company's product " Rocksil " rock wool insulation. Photographs of the company's dolomite quarry in Argyllshire, the raw material of " Rocksil," will be seen with examples of the rock itself. A vibration test will demonstrate the materials great resilience and resistance to shakedown.

To be devoted entirely to exhibiting " Clayton-Still " wire wound heat transfer tubes, **Clayton Dewandre Co., Ltd.'s** exhibit **(15OG)** will be divided up into five-sections, each covering separate fields of application. These will be high temperature, alternator cooling, refrigeration applications, heating and ventilating, and process and chemical. The " Clayton-Still " tube is of unique construction, the extended surface consisting of a continuous wire wound into elongated loops which are each firmly bonded to the basic tube in a helical formation. As the rate of heat exchange to or from a small diameter wire is extremely high, the resultant large dissipating surface, aided by air turbulence induced by the formation of the wire, gives a very high coefficient of heat transfer. Production methods are such that surface ratios, loop width and height, gauge of winding wire and density of winding can be varied easily to facilitate the provision of tubes for any specified purpose whilst eliminating special procedures and high manufacturing costs. The tubes can be supplied in up to 25 ft lengths, with basic tube diameters of from ¼ in. to 3 in. and over-wire diameters of ¾ in. to 4½ in. The materials may be copper,



" Clayton-Still " wire wound heat transfer tubes to be exhibited on stand No. 15 OG

copper alloys, brass, mild steel, stainless steel, etc., and if the basic tube is of annealed copper or copper alloy, the finished product can be bent to any desired shape without difficulty. Two special types of tube have been developed with the surface extended also within the bore, for special applications such as oil cooling or heating where the poor heat transfer properties of the fluid cause a high resistance to heat flow. One of these has an insert of normal " Clayton-Still " wire loops which, if required, can be firmly soldered to the tube, whilst the other, particularly useful when very dirty liquids are involved, has three small diameter plain tubes inserted and soldered in the bore. For those applications where the working temperatures are too high for the soft-solder bond a method of induction-brazing the wire winding to the tube has been evolved, using a range of copper-silver brazing alloys. The latest development is the production of an all-steel tube, with the loops welded to the basic tube, for use in installations involving very high temperatures.

The largest item which the **Consolidated Pneumatic Tool Co., Ltd., (6C),** will exhibit will be one of their class FE range of compressors, on show for the first time at this exhibition. The design of this range of horizontal, double acting balanced opposed compressors, lends itself to construction in a large number of sizes suitable for a wide range of applications. Thus, by varying the sizes of cylinders, or increasing the number of crank throws, units can be supplied for such widely varying needs as the supply of compressed air at 40 lb/sq.in., or for various industrial processes requiring up to 3,000 lb/sq.in., whilst capacities of up to 5,000 cu.ft/min are obtainable.

Crane Ltd., (9G), are supporting the exhibition with a display of bronze, cast iron and steel valves for use with steam, water, gas, oil and air, for high as well as low pressures, and from sub-zero temperatures rising to 1,200 F. Size range is for pipe-lines from ⅛ in. up to 24 in. One standard item to be included will be an example of a Crane 16 in. cast steel valve, weighing approximately 1½ tons and standing about 9 ft high. This giant is used for controlling high temperature fluids and

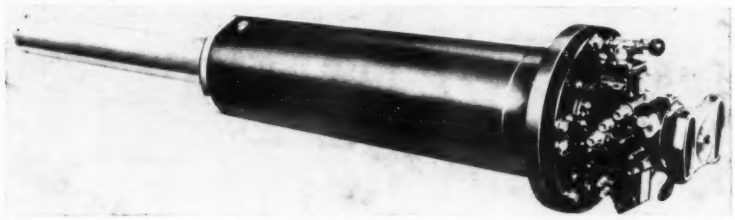
gases. A particular point of interest will be its Crane patent flexible wedge disc which is incorporated to overcome sticking, especially in high temperature service. The valve will be motor-operated, either by direct application or remote control. Additional items will include examples of Crane malleable iron pipe fittings, forged steel flanges, and other materials associated with pipe-lines.

Felco-Hoists Ltd., (7B), will be showing a selection of their well-known range of lifting tackle, including hand operated chain blocks, overhead trolleys, travelling chain blocks, ratchet hoists, "Adjust-A-Leg" equalizing slings and hydraulic jacks. Electrically operated exhibits include electric travelling chain blocks, electric wire rope pulley blocks, " Baby 60 " hook suspension type electric chain blocks, and the hydroist electro-hydraulic wire rope hoists. In addition, they will exhibit a portable gantry crane.

Exhibits by the **Graviner Manufacturing Co., Ltd., (3M)** will include: industrial explosion protection and suppression equipment, thermostats and overheat switches, fire detectors, fire extinguishing apparatus, specialized nuclear energy equipment including graphite components and lead-shielding blocks, oil mist detector for marine engineers and Graviner high sensitivity detector for diesel petrol and dual fuel engines. A working model and a continuous film will illustrate how the industrial explosion protection and suppression equipment operates, and a " Spot-a-Fire " resetting detector and "Gravinette" will be shown. Three new items added to the range of equipment developed by the Graviner Manufacturing Co., for explosion protection and suppression for industry which will be shown will be a Graviner combined detector and suppressor unit, high speed butterfly valve, and a photo-electric explosion detector.

Fuel cans for the UKAEA will be shown by the **Hawker Siddeley Group (40, 5P),** though their chief exhibit will be an interesting and comparatively new form of power generator—a free piston gasifyer turbine installation, shown by National Free Piston Power Ltd., and manufactured by The National Gas and Oil Engine Co., Ltd., and Brush Electrical Engineering Co., Ltd. Described as a bridge between the oil power age and the atomic age, this new conception of packaged power is recognised as an efficient new contribution to meeting the ever increasing power needs of the world. Other exhibits will include high-speed, lightweight air-cooled diesel engines, a handraulic starter, and various items of precision electronic equipment.

To be exhibited by **H. M. Hobson Ltd., (7OG),** will be reactor control units and nuclear ancillary equipment, together with examples of industrial telegauges, pressure manometers, flowmeters and hydraulic pumps and motors, typical of the products the company have supplied to the United Kingdom Atomic Energy Authority, and other engineering industries. The exhibits comprise (1) gearboxes for the master, slave, fine and safety controls of reactor control systems; (2) the " Hobson-AERE " honeycomb isotope unit, designed for isotope irradiation; (3) a half scale working model of the honeycomb isotope unit for demonstration purposes; (4) the " Hobson-CRL " master slave manipulator for the remote handling of radioactive or toxic materials; (5) examples of " Hobson " industrial telegauges for remote indication of tank contents or liquid level, and pressure indicating manometers including twin leg differential pressure and barometer and absolute pressure gauges; (6) " Integral " Type 180, Mk. 43 hydraulic pump. A seven cylinder radial-piston pump with initial gear stage; (7) " Integral " Type 197, Mk. 2 hydraulic motor. A seven cylinder swashplate motor of reversible rotation and low inertia; (8) " Integral " twin-channel mass reading flowmeter, Mk.2 giving independent and combined rate-of-flow and total consumed over a flow range of zero to 300 lb/min, and (9) " Integral Everac " high precision chuck, operated by internal hydrostatic pressure and entirely self-contained.



(*Above*) **Hobson-AERE Honeycomb isotope unit (Stand 7OG),** (*Below*) **No. 15 Aristocrat centrifugal fan to be shown by Keith Blackman Ltd. (A1)**

The chief feature of the **Ilford Ltd., (5BB),** exhibit is the display and demonstration of the wide range of equipment and materials for plan and document copying by the Azoflex dyeline process. The Azoflex method of dyeline reproduction is widely used in industry and commerce because of its high productivity, great economy, absence of fumes and freedom from installation costs. A new addition to the range this year is the very economical Azoflex 105 machine which is particularly suited to the needs of the commercial and small industrial establishment.

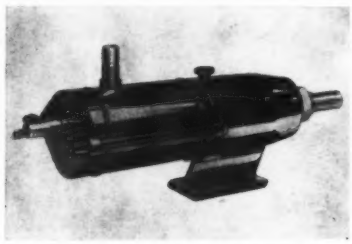
Exhibited for the first time by **Industrial Hydraulics Ltd. (16A),** will be a revolutionary new pipe coupling known as the Keela-Tite coupling. This has been developed essentially to meet the exacting requirements of modern high pressure hydraulic installation work, but it is also suitable for a wide range of other applications. The coupling has been thoroughly proved over the last three years under both steady and fluctuating pressures, and several installations have been successfully completed in fields as far removed as coal mining and commercial vehicles. Also shown for the first time will be the recently announced liquid sealed hydraulic accumulator, already made in a range of sizes to give capacities of 1, 2, 4, 6 and 8 gal/min. Large sizes will be available shortly. A working exhibit will demonstrate clearly the principles of operation.

For many visitors the outstanding exhibits on the **Keith Blackman Ltd., Stand (A1),** will be two of the new, compact and attractively finished (grey and royal blue) "Aristocrat " centrifugal fans. These are being shown for the first time at any exhibition. Advantages of the"Aristocrat " are its low sound level in operation, a large volumetric capacity and good efficiency over a wide operating range and sturdy construction. The fan is for heating and ventilating applications, air conditioning and general ventilation with an initial capacity range up to 9,000 cu.ft/min at 3.5 in.s.w.g. Representative of the company's scope in the large fan field is a 70 in. type AR impeller with backward bladed aerofoil section blades providing efficiencies of up to 90 per cent. This fan is used for induced draught, air conditioning and mine ventilation purposes and handles large air volumes against moderately high resistances. Photographs will depict other large and heavy fan types. The stand is intended to display a cross-section of the " Tornado " range and will also cover equipment relative to clean air and dust extraction together with standard stock fans such as the bifurcated fume removal unit, the APA ventilating fans and the four-way welding fume exhaust unit.

Modern Wheel Drive Ltd., (C7), will be showing a running model, for operation by visitors, of a Hindmarch/MWD four-input single-output oil-operated reverse-reduction gearbox, type 4MWR. Also working on this stand will be a full-size standard Hindmarch/MWD single-engine oil-operated reverse-reduction gearbox, type MWKR, to transmit 630 b.h.p. at 750 rev/min, gear ratio to suit requirements. The operation of the clutches will be visible through transparent covers.

Mono Pumps Ltd., (28), will demonstrate the Mono powder pumping system by circulating powder through a pipe circuit.

A P12 Mono powder pump is used in conjunction with very little fluidizing air to ensure the powder behaves in a similar way to fluid along a horizontal or up a vertical pipe. The industrial pumping division will display a complete range of pumps for handling free-flowing, viscous or abrasive fluids. The new Mono Kwikleen pump and the " D " type cast iron pump will be shown



The heart pump developed by Mono Pumps Ltd., which could be adapted for laboratory use

as working units. Of interest on the stand will be the pump developed in collaboration with a team of surgeons for pumping human blood with the minimum damage to the red corpuscles. The pumping unit can be autoclaved as a single cartridge and it has possible application to research work or pilot plants where liquids may be easily damaged and the utmost hygiene is required.

For some years the expanding research facilities of **D. Napier & Son Ltd. (R2),** have been placed increasingly at the disposal of other companies, notably those within the English Electric Group. In showing specimens of their research work Napier have had to contend with severe space limitations, and the list of proposed exhibits originally submitted covered not only many different branches of research but also many different branches of engineering. Those finally chosen were selected because they illustrate interesting developments but, at the same time, do not take up much space. Among these will be examples of the company's titanium welding. The company has had seven years' experience in the joining and fabrication of titanium based materials, and the exhibits, showing examples of fusion and resistance welding, will be standard production items.

Newman, Hender & Co., Ltd., (9J), is exhibiting a selection of bronze gate, globe and check valves, cast iron and steel gate valves, forged steel valves and fittings. Of special interest will be " Newman-Milliken " lubricated parallel plug valves, " Newman-McEvoy " automatic self-sealing conduit gate valves, " Vee-Reg " combined stop and regulating valves, the " Newman-Seaman-Snap " air/gas valve and " Newman-Velan " gate and globe valves. Valves and fittings specifically designed for the nuclear field will also be displayed.

New Welbeck Ltd., (46OG), are exhibiting their range of versatile " Master " portable suction cleaning equipment. All models are designed on a " no dust bag " principle and embody all the advantages to maintain maximum suction under normal working conditions. By dispensing with a dust bag this ensures a free air flow which is otherwise restricted by the contents of the bag causing loss of suction power during operation. All New Welbeck models are fitted with detachable and interchangeable power units and can be supplied in a wide range of voltages from 24v upwards for use on a.c. or d.c. current. A wide range of accessories are available and special attachments can be produced to order. The nuclear industry has already recognized the advantages of using New Welbeck " Master " cleaners and many machines have been installed at some of the nuclear power stations already in operation. Special attention has already been given to the particular problems associated with this sphere of industry where machines are liable to contact with materials and to undergo irradiation. Where non-compatible materials are undesirable such as aluminium, components are encased in a bonded heavy duty polythene sheath. When machines are to be used in areas where materials are easily damaged or are brittle such as graphite, resilient rubber buffers are fixed to the bottom and around the canister. It is possible to filter the air exhaust for use in ultra-clean areas by fitting an exhaust filter.

Plessiflex stainless steel, seamless, flexible hose will be displayed by **Power Auxiliaries Ltd., (9CG).** Used mainly for the remote handling of fuel elements in nuclear reactors, Plessiflex is also used as the flux count hose, which contains an electric cable, to measure flux between nuclear fuel elements and control rods. In addition, the hose has been developed for use with a special small diameter television camera, which is lowered into the reactor to watch the fuel element charge and discharge working. Within the reactor, Plessiflex is used to connect the stack pipe valves to the burst slug detection (B.S.D.) pipes. Further uses for Plessiflex are constantly arising and power auxiliaries have been asked to develop semi-open pitch tube which can be substituted for rigid pipes running from within the reactor to the control room. Ducting uses for Plessiflex are also being investigated for gallery services on top of nuclear reactors where large diameter ducting from 3 in. to 7 in. is required, and on the charging machine which is used for fuel element handling. In the latter instance, the ducting needs to be pressurized to above the nuclear reactors pressure before the charge machine valves are opened. Therefore, these charge machine pressurization hoses would need to withstand an internal working pressure of 150 to 350 lb/sq.in. The hoses are of 3 in. diameter upwards and from 45 ft to 75 ft in length.

The publishers of NUCLEAR ENERGY ENGINEER, **Princes Press Ltd. (5IG),** will be putting on a display of their technical journals, CONSULTING ENGINEER, HEATING AND AIR TREATMENT ENGINEER, CIVIL ENGINEER, and, of course, NUCLEAR ENERGY ENGINEER. Copies of their books, *Physics is Easy* and *Mathematics is Easy*, both by NUCLEAR ENERGY ENGINEER science editor D. S. Watt, BSc, will also be displayed. A film depicting the various departments of the company, including their printing works at Kennington, will be shown throughout the exhibition.

Renold Chains Ltd., (6H), will be showing a selection of Renold transmission chains from .25 in. pitch to 4.0 in. pitch, together with a selection of stock drives. Chains for camshaft and auxiliary drives for diesel engines will be included, together with a selection from the Renold range of conveying and elevating chains from 3,000 lb to 85,000 lb breaking load, and The Coventry Mark 5 malleable replacement chains with special attachments. Power transmission accessories, including chain and flexible couplings and chain tools will also be displayed. A working model will demonstrate the use of the Renold sprag clutch on a torque convertor and will be supported by details of other applications of this product.

One of the more important exhibits on the **Rockweld Ltd., (U2),** stand will be the Autopak arc welding equipment. This, the makers believe, could be the first step towards the welding transfer line. Its system of control for the welding head and for the carriage is particularly adaptable to the realization of automation in the fabrication shop. The Autopak is a versatile unit incorporating a new conception in automatic arc voltage control. The system of control is sensitive, although the Autopak is a robust machine for the fabrication shop and the machine itself is free from costly elaborations, portable, and easy to maintain and operate. Its uses have been considerably extended by the addition of a boom mounting for the self-propelled carriage. It is 20 ft long and can be mounted at varying heights on a wheeled "A" frame. This enables the equipment to make butt, fillet and lap welds up to 17 ft 6 in. long at any desired height above floor level. Also worthy of considerable attention will be the demonstrations of the Rockweld carbon dioxide welding process (the Comet Process). In this an arc is struck between a special composite continuous wire and the work piece in an atmosphere of carbon dioxide gas. The wire contains the de-oxidizing agents and the slag-forming materials; the carbon dioxide protects the metal from atmospheric contamination during transfer and in the weld pool. It is, therefore, a visible arc process, readily adaptable for both automatic and semi-automatic operation.

Rotaprint Ltd., (14IG), will be exhibiting three of their small offset machines designed to produce all classes of printing and duplicating. The R.70 model is used extensively for stationery and duplicating of all kinds. The R.40/80 model prints in addition, the finest of full-colour work on an even wider range of paper or card. The R.30/90 model, a larger and even more versatile machine, can be used for printing everything from simple office forms to high-quality sales brochures in sparkling superimposed colour. It will print at a speed of up to 6,000 impressions/hr.

Almost every skin hazard occurring in the engineering, marine, and welding industries can be countered by the use of one of the wide range of barrier creams manufactured by **Rozalex Ltd., (22IG),** specially formulated for the United Kingdom Atomic Energy Authority was their cream No. 13, the prime function of which is to make it easier to de-contaminate protective clothing

worn by personnel exposed to radio-active materials. Until cream No.13 was developed, protective clothing was extremely difficult to cleanse. Now the same clothing can be re-issued fairly quickly, with cream No.13 making de-contamination a much simpler and more rapid process. Two of the latest Rozalex creams to be on display are the Waterless Skin Cleanser and the Stain-Removing Cream, both of which have been extensively field tested with outstanding results. Non-abrasive and completely harmless to the skin, the Waterless Skin Cleanser is simply applied to the contaminated skin area and gently rubbed, liquefying and emulsifying dirt and grime, and the skin may then be wiped clean and dry with a paper tissue or other convenient material. Where water is not available this is the ideal cleanser. Rozalex Stain-Removing Cream provides a safe and efficient method of removing stubborn skin stains. The cream is rubbed thoroughly over the contaminated area and washed off with water—taking the stains with it.

On **Stand No. 16IG, A. Schrader's Son** Division of Scovill Manufacturing Co., will demonstrate aspects of air control suitable for the mechanization of repetition movements normally found tiring and tedious to the manual operator. Schrader products include: air cylinders (single and double-acting types providing pushing or push-and-pull movements), air presses (for stamping, broaching, riveting, shaping, assembling, etc. Single-acting and double-acting types), air ejection sets (specially designed for ejecting, by means of an air blast, finished work from presses, etc. Easily adjustable to synchronize with any stage of the machine operation), control valves (for the actuation of air circuits. The range includes two, three and four way types, also those for hand, foot, pilot or solenoid operation), quick-acting couplers (to permit plugging in tools or equipment to any part of the air line) and blow guns.

Silentbloc Ltd., and their subsidiary, **Andre Rubber Co., Ltd., (4IR),** will be exhibiting rubber-metal products ranging from miniature Silentbloc units for mounting delicate instruments to rubber bearings manufactured by Andre Rubber for mounting bridges. A very wide range of Silentbloc anti-vibration mountings, flexible bearings and couplings will again be in evidence. Andre Rubber will show, apart from their range of bonded units, their most recent product, the Raykin Fender unit, a particularly interesting piece of rubber-metal engineering which has already been installed in several important harbours and jetties throughout the world.

Sintering and Brazing Furnaces Ltd., (9IG), will be showing a selection of their electric furnaces. Principal exhibit will be a 1,350°C. high temperature sintering furnace with push-pull boat conveyance system. Heating elements are of molybdenum. Among the other exhibits will be the company's 1,800°C. sintering furnace which is widely used by the UKAEA.

Stein Atkinson Vickers Hydraulics, Ltd., (9M), will be showing a representative display of their British-made "Vickers-Detroit" oil hydraulic pumps, motors, control valves, actuating cylinders, power assisted steering boosters, and complete power units. Special attention will be given to the new range of high performance vane type pumps for 2,000 lb/sq.in. and 2,000 rev/min duty, and to a new temperature and pressure compensated flow control for speed control of actuating cylinders regardless of change in workload and oil viscosity.

Displayed on the **Sternol Ltd., Stand 37IG,** will be a wide range of products including all types of marine lubricants, detergent diesel cylinder oil with basic characteristics for use with heavy fuels, Protexon H.D. sea spray corrosive preventive, and Supplement I (Panther), Supplement II (Puma) and Supplement III (Cougar) diesel engine oils. A full range of Dectoyl industrial oils, as well as Dectoyl gear lubricants for heavy industrial gearing, will be shown together with a wide range of oils for machine shop use, including Sternosol-Six soluble oil and Tapoyl straight cutting oils. Foundry visitors will be able to see samples of the various Sternocore binders which include powders, creams, semi-solids and oils. Technical staff will be in daily attendance, and descriptive literature will be available.

Several new Sifbronze products made by **The Suffolk Iron Foundry (1920) Ltd., (3Y),** will be on display for the first time. These include Sifbronze process "101," Sifbronze "104" rods and the S.I.F.-Colibri cutting machine. Sifbronze process "101" comprises the new Sifbronze filler rod "101" and a new tinning flux which the company has developed especially for cast iron, and it is said to produce joints infinitely superior to anything previously obtained. The old sluggishness of flow across the joint face has been completely eliminated and a far greater degree of "penetration" of bronze into the parent metal makes "peeling" of joints a thing of the past. The S.I.F.-Colibri cutting machine gives a smooth and steady action which ensures perfect cutting under all conditions of working.

Swallow & Hicks Ltd. (20IG), will be exhibiting a comprehensive range of specialized plan filing and drawing-office equipment. This will include a draughtsman's back reference table in steel, which is entirely new and of unique design. It can be easily dismantled for transportation and storage purposes and includes a drawer to take D.E. size drawings, together with a personal lockable instruments drawer complete with a pull-slide.

Talbot Stead Co., Ltd., (9AA), will concentrate on products and equipment made for nuclear power applications, including a pressure vessel, breeder thermocouple guide tubes, fuel element support, restraint bar and charge plug. In addition the company will be showing scale models of a control rod (fabricated from stainless steel with boron inserts), restraint bar (fabricated from mild steel. Outer tube with four other tubes inserted. Centre bar inserted in the smallest tube) and a charging standpipe assembly (fabricated from mild steel. Upper portion consists of outer tube concrete filled with four tubes inserted. Lower portion consists of large tube with smaller tube fixed on outer wall). As well as the nuclear exhibits Talbot Stead will be showing:—Swirlyflo tubing, Forjend fittings, stainless steel tubing, carbon and alloy tubing, flanges and machined parts, plug cocks and the "Cupford" valve, "Metior" stainless steel fittings, bright drawn bar and wire, bi-metal tubing, "Metica" metal-clad carbon and graphite tubing and manipulated and fabricated parts.

Teddington Aircraft Controls Ltd., (13OG), will show their range of stainless steel bellows for expansion joints suitable to a wide range of specialized applications in the nuclear, gas, petroleum, marine, chemical and general engineering fields. The increased use of high temperature piping and ducting has brought in a great demand for the stainless steel butt-welded type in which Teddington specialize. Bellows are produced from ½ in. to over 7 ft in diameter. Also on show will be the results of developments during the past 12 months, in which time a range of rectangular units has been produced, some measuring 24 ft × 24 ft for flues and boiler uptakes on large land boiler installations at power stations in the U.K. An even larger installation is on the board, using segments of the expansion joint which will weld together on site to make a roughly circular assembly 78 ft in diameter. These large rectangular assemblies are made from stainless steel to combat corrosion problems and keep them structurally light, and are usually supplied with mild steel flanges for bolting attachment. They have special radius corner pieces to distribute stresses properly, and so prevent the stress concentration at the corners which inevitably occurs with a mitre joint. Internal sleeves are optional, and each expansion joint is individually designed to meet the customers problem of size and movement.

Tubes Ltd. (9A), will be showing their latest developments in cold finished extended surface seamless steel tubes for use in nuclear power and other installations where maximum heat transfer efficiency is necessary. This type of seamless tube is of very recent manufacture and has not been exhibited before.

Distington Engineering Co., Ltd., a member of the **United Steel Companies Ltd.,** group **(P6),** will be showing a large press frame casting and a model of an atomic waste "coffin" of the type used by the Atomic Energy Authority will indicate the versatility of that company's large iron foundry. Distington are also showing a section of the new design of ropebelt conveyor which they successfully put on the market last year. Another company of the group, the **Appleby-Frodingham Steel Co.,** are featuring the production of iron and steel by means of two large colour dioramas which give a realistic impression of actual steelworks operations. Forging activities form the centrepiece of **Steel, Peech and Tozer's** display, a large colour picture of the company's 2,000 ton forging press being supplemented by small-scale models of 21 types of forging to give an idea of the plant's capacity. The architectural use of

(*Continued on page* 228)

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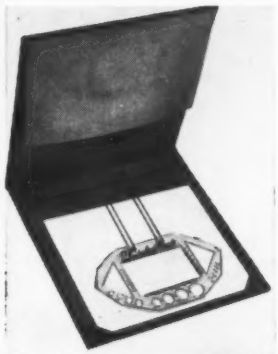

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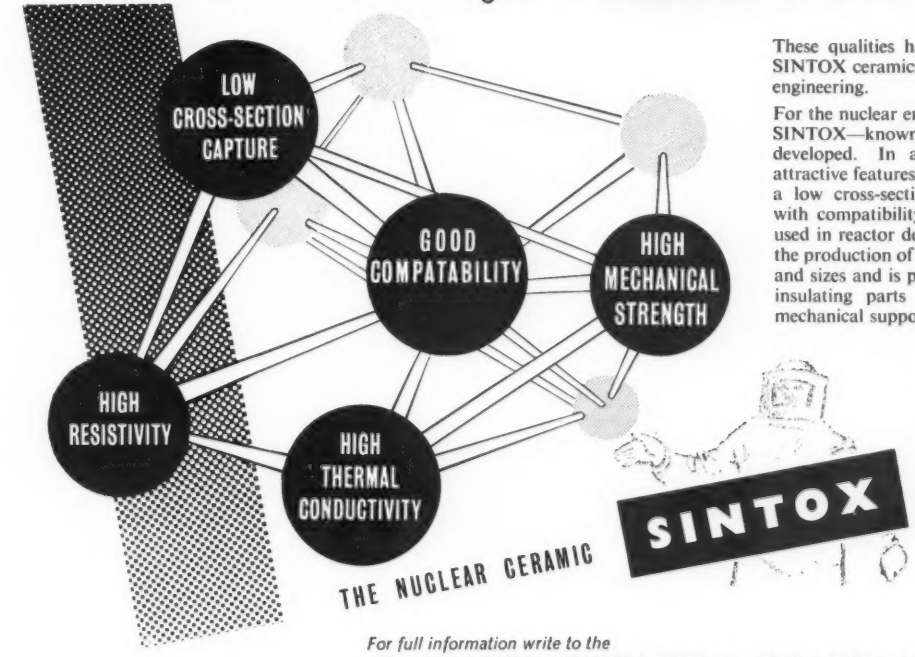

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stainless steel curtain walling is being demonstrated by **Samuel Fox and Co., Ltd.,** who also plan to exhibit several items representing special steels, including turbine blades and a large cylinder bolt used in power station turbo-generators. Examples of woven fencing in stainless steel will draw attention to the advantages of this material over conventional steel fencing.

Vacu-Blast Ltd., (6W), will be exhibiting four of their range of mobile dust free shot blast machines. The " Major " machine with pipe cleaning attachments together with the " Medium " and " Junior " machines, will be available for demonstration throughout the period of the exhibition. The display will also include a range of attachments for plate edge cleaning and blast cabinets for use with Vacu-Blast machines. It is significant to note that shot blasting operations will be carried out in a public exhibition hall without recourse to protective clothing or special enclosures.

"Vacu-Blast" machine being used to clean inside of large steel vessel

The Vacu-Blast machine incorporates a closed circuit pressure-vacuum system for the supply of abrasive to the work surface and recovery of spent abrasive, dust and debris. The machine separates and cleans the abrasive, the dust and debris being abstracted from the air stream, with the finest particles of dust finally filtered from the exhausted air. Sometimes a job arises which needs Vacu-Blast but, because of the complexity of its surface or difficulty of access, it is not a practicable application for the established closed circuit Vacu-Blast system. In these circumstances it is necessary to have the unrestricted movement characteristic of the open-blast nozzle, whilst retaining the dust recovery feature of the Vacu-Blast system. This combination has been attained in the technique now known as " Open Vacu-Blast," the introduction of which has shown quite conclusively that the main difficulties associated with open blasting derive from the dust which is released into the atmosphere, fouling the air and obscuring the vision, thereby making the whole operation difficult and hazardous. The open Vacu-Blast method employs a modified type of gun head which is held some 3-4 in. from the work surface, thereby obtaining the free movement of an open blast nozzle but with the important difference that the dust is drawn off the surface local to the point of impact and retained in the closed system of the Vacu-Blast machine. The abrasive expended on the work surface is recovered at the end of the blast cycle by use of the high vacuum generated in the dust collector. During its passage through the machine all remaining dust and debris is abstracted from the abrasive, thus providing cleaned abrasive for re-use at the commencement of the next blasting cycle. In order to maintain an economical blasting cycle on open Vacu-Blast applications Vacu-Blast Ltd., have designed a further version of their Major 130 N.C. machine which is known as the Major Mark II. This machine gives sufficient capacity for approximately 30 min open Vacu-Blasting, enabling a large area to be cleaned in each cycle, after which, the spent abrasive can be recovered in a matter of a few minutes and blasting may then be resumed. The Major Mark II has been designed as an all-weather model for work out of doors; it is equally well suited to indoor work where the shot blasting of large components on the shop floor can save expensive transportation to and from a fixed shot blast installation. Major Mark II machines are currently in use on nuclear power projects, where they are employed to establish " clean conditions " within reactor vessels, heat exchangers and ducting.

The Walterisation Co., Ltd., (18OG), will be exhibiting industrial products, the protective pretreatment of which has been carried out by one or other of their processes. These are utilized in all forms of industry to ensure corrosion resistance and paint-bonding, with eye appeal. The range of Walterisation processes comprises phosphate treatments, derusting, cold brush-on and spray treatments, chemical oxidation processes, as well as specialized treatments. The scale removal jelly, Waltergel, will also be on show as will the newest addition to our range, SPC, a cold spray phosphate treatment. Also on display will be parts manufactured by cold extrusion. This process, which offers considerable economy in costs for quantity produced blanks, has been applied to the production of heavily drawn and formed articles which in many instances have hitherto only been manufactured by hot forging.

Emphasis at the **Westinghouse Brake and Signal Co., Ltd., Stand (15F),** will be on the company's activities in the pneumatic control field. A controllable pitch propeller and a mock up of a marine engine and gearbox, both remotely controlled and operated by means of a pneumatic system from a bridge, will be shown. Also a working exhibit representing an excavator control cabin will demonstrate the ability of pneumatic apparatus to cater for a wide variety of controlled movements, and will show how Westinghouse controls give the driver " finger tip " operation of the main earth moving functions. Backing up these exhibits will be static display of typical pneumatic valves and cylinders, together with a film showing various applications of this apparatus. Pneumatic control has become increasingly popular over the last few years and systems can now be offered which range from a simple throttle control to a completely interlocked layout for controlling such installations as multi-engined ships and large power stations.

Worthington-Simpson Ltd., (4S), will be showing a representative selection of centrifugal, steam and marine pumps from their wide range of products, together with rotary and " Monobloc " air compressors and a marine condensing plant complete with inter and aftercooler, ejector, and extraction pump. One of the " Monobloc " pumps will feature the new Worthington-Simpson flameproof motor enclosure. A central priming unit will be displayed as a working model. Maximum capacities of the pumps exhibited will be 3,900 gal/min. with heads up to 600 ft. The Worthington-Simpson central priming unit which will be on show is designed to provide a reliable means of priming for installations involving a number of non-self priming centrifugal pumps. The unit consists of a centrifugal primer, a recirculating tank, and a vacuum tank. The primer is of patented "Monobloc" construction, model PM3. It operates on the water ring principle wherein a ring of water is rotated in a specially shaped casing by a revolving vaned wheel. The shape of the casing causes the water to reciprocate radially between the vanes of the wheel.

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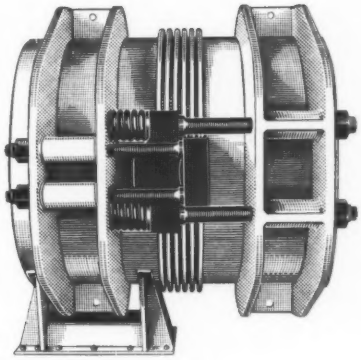

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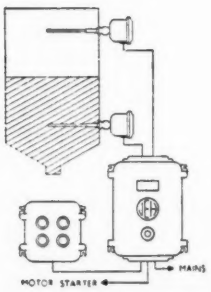

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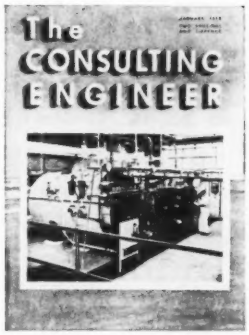

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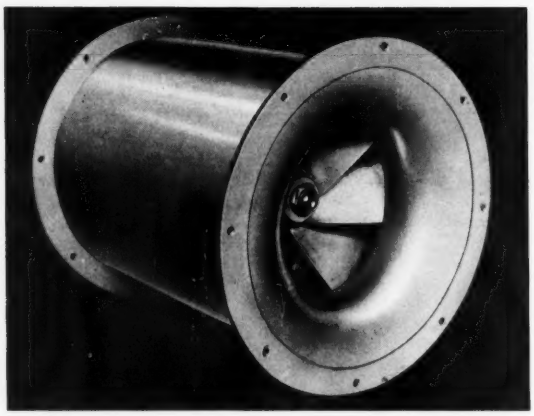

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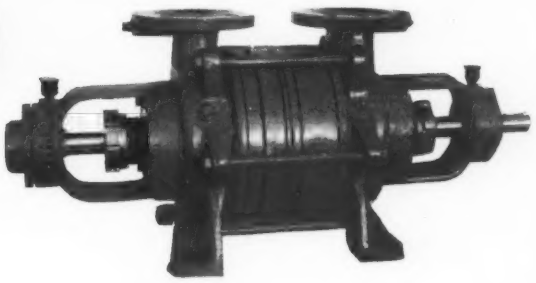

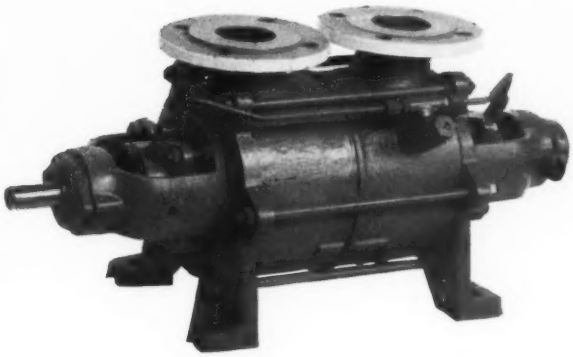

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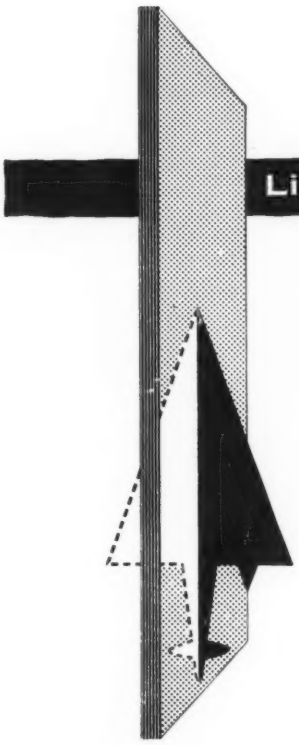

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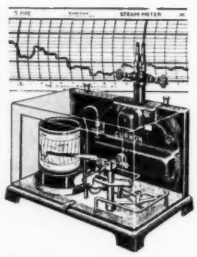

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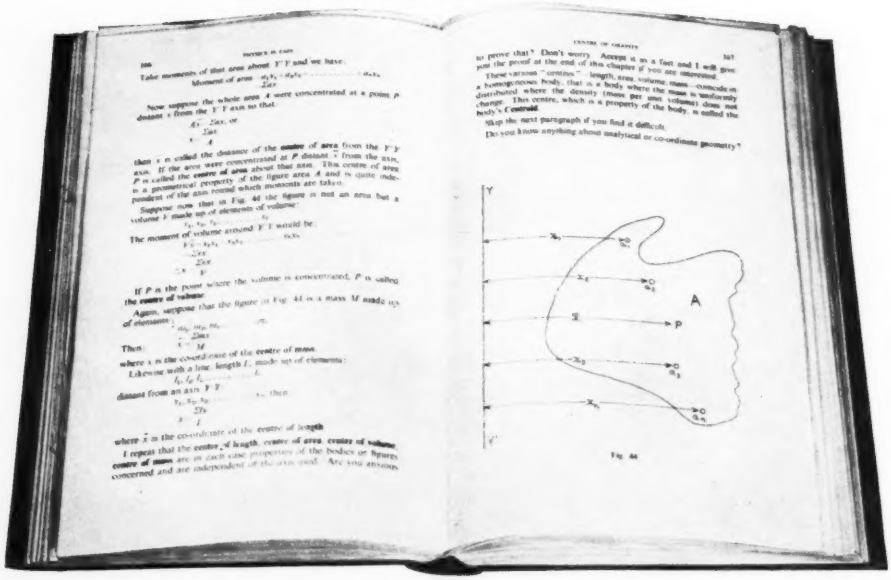

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RESEARCH REACTORS		
Materials Testing Reactor (MTR) (Des. ORNL & ANL)	40 MW	—
Engineering Test Reactor (ETR) (Des. G.E.C.)	175 MW	—
BNL Graphite Reactor, Brookhaven	30 MW	—
Bulk Shielding Reactor (BSR) (Des. ORNL)	0.5 MW	—
Chicago Pile 5 (CP-5) (Des. ANL)	2 MW (10 MW by June, 1959)	—
Plutonium Recycle Test Reactor, Hanford (Des. G.E.C.)	70 MW	—
Gas Cooled Reactor Experiment (GCRE)	—	—
PRODUCTION		
Hanford (8 reactors) (Des. ANL)	—	—
Savannah River (5 reactors) (Des. ANL-Dupont)	—	—
CIVILIAN POWER REACTOR AND REACTOR EXPERIMENTS		
Water Cooled		
Shippingport (PWR) (AEC-Duquesne Light Co.) (Des. Westinghouse)	231 MW	60 MW (100 MW-1961)
Boiling Reactor Experiment No. 4 (BORAX-4) (Des. ANL)	15.5 MW	2 MW
Experimental Boiling Water Reactor (EBWR) (Des. ANL)	20 MW (100 MW by late 1959)	4.5 MW
Vallecitos Boiling Water Reactor California General Elec. Co. and Pacific Gas & Elec. Co.) (Des. G.E.C.)	20 MW	5 MW
Argonne Boiling Reactor (ARBOR)	200-600 MW	—
Dresden (BW) (Commonwealth Edison Co.) (Des. G.E.C.)	626 MW	180 MW
Indian Point (PWR) (Consolidated Edison Co. of N.Y.) (Des. Westinghouse)	585 MW	163 MW + 112 MW (Oil fired)
Yankee Atomic Electric Co. (PWR) (Des. Westinghouse)	392 MW (480 MW by 1961)	110 MW (134 MW by 1961)
Elk River (BW) (AEC-Rural Co-operative Power Ass.) (Des. ACF)	73 MW	22 MW
Sioux Falls (BW) (Northern States Power Co.) (Des. Allis-Chalmers)	203 MW	62 MW
Carolinas-Virginia (PWR) (Nuclear Power Associates, Parr Shoals) (Des. Westinghouse)	160.5 MW	17 MW
Pacific Gas & Elec. Co. (BW), Humboldt Bay (Des. G.E.C.)	171 MW	50-60 MW
U.S. Military Programme (PWRs) Submarines U.S.S. *Nautilus* (1955), *Skate* (Oct. 1957). 16 further submarines, gui submarine reactor prototype. (All under construction.)		
Army Package Power Reactor No. 1 Fort Belvoir (APPR-1) U.S. ARMY (Des. ALCO)	10 MW	1.85 MW
APPR-1a, Alaska	20 MW	—
Argonne Low Power Reactor (ALPR) (BW) (N.R.T.S.)	3 MW	200 kW
AQUEOUS HOMOGENEOUS REACTORS		
Homogeneous Reactor Experiment (HRE-2) (Des. ORNL)	5.2 MW	300 kW
Los Alamos Power Reactor Experiment (LAPRE-2) (LAPRE-1 dismantled)	1 MW	—
SODIUM REACTORS		
Sodium Reactor Experiment (SRE) (Santa Susana) AEC-Southern California Edison Co., (Des. N.A.A.)	20 MW	5 MW (by 1958)
HALLAM (Consumers Public Power District-AEC) (Des. N.A.A.)	245 MW	75 MW
Chugach Electric Assn.-AEC, Alaska (Des. N.D.A.)	40 MW	10 MW
Military Programme		
Submarine U.S.S. *Seawolf*	—	—
LIQUID METAL REACTOR		
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ORGANIC MODERATED REACTORS		
OMRE (Des. N.A.A.)	5-15 MW	—
Piqua City-AEC (Des. N.A.A.)	45.5 MW	11.4 MW
GAS COOLED REACTOR		
East Central & Florida West Coast Nuclear Groups (Des. Gen. Nuclear Eng. Co.)	173 MW	46 MW
FAST REACTORS		
Experimental Breeder Reactor No. 1 (EBR-1) (Des. ANL)	1.4 MW	100 kW
Experimental Breeder Reactor No. 2 (EBR-2) (Des. ANL)	62.5 MW	16.5 MW
Los Alamos Molten Plutonium Reactor Experiment No. 1 (LAMPRE-1)	1 MW	—
Enrico Fermi Plant (Power Reactor Dev. Co., Lagoona Beach) (Des. At. Power Dev. Ass.)	300 MW	90 MW (1961) 140 MW (1962)

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...Electrical ...utput	Fuel	Moderator	Coolant	Thermal Flux	Outlet Temp.	Start-up
—	90% U^{235}	H_2O	H_2O	5.5×10^{14}	46°C.	1952
—	90% U^{235}	H_2O	H_2O	5×10^{14}	59°C.	1957
—	90% U^{235}	Graphite	Air	1.5×10^{13}	177°C.	1950
—	90% U^{235}	H_2O	H_2O	10^{13}	—	1950
—	90% U^{235}	D_2O	D_2O	1.5×10^{12}	51°C.	1954
—	—	D_2O	D_2O	—	—	1960
—	—	—	—	—	—	1959
—	Nat. U	Graphite	H_2O	—	—	1944-55
—	—	D_2O	D_2O	—	—	By 1955
...0 MW ...MW-1961)	Seed: highly enriched Blanket: Nat. U	H_2O	H_2O	Seed: 6×10^{13} Blanket: 4×10^{13}	282°C.	Dec. 1957
...MW	About 90%	H_2O	H_2O	—	215°C.	1956
...5 MW	1.44% U^{235}	H_2O	H_2O-Steam	10^{13}	254°C.	1956
...MW	Fully enriched	H_2O	H_2O	2.8×10^{13}	285°C.	Oct. 1957
—	About 90% enriched	H_2O	H_2O	—	335°C.	1960
...0 MW	1.5% U^{235} enriched	H_2O	H_2O and steam	—	283°C.	1960
...MW + ...2 MW ...il fired)	Up to 90% enriched	H_2O	H_2O	2×10^{13}	271°C.	1960
...0 MW ...W by 1961)	3.1% U^{235} enriched	H_2O	H_2O	2×10^{13}	273°C.	1960
...2 MW	Slightly enriched	H_2O	H_2O	2×10^{13}	278°C. (steam)	1960
...2 MW	1.6% enriched	H_2O	H_2O	8×10^{13}	254°C. (steam)	1962
...7 MW	—	—	D_2O	—	—	1962
...60 MW	—	—	—	—	—	1962
...bmarines, guided missile cruiser (2 reactors), large ship reactor prototype (2 reactors), small						
...35 MW	UO_2 highly enriched	H_2O	H_2O	2.7×10^{13}	232°C.	April, 1957
—	—	—	—	—	—	1959
...00 kW	Highly enriched	H_2O	H_2O	—	—	1958
...00 kW	UO_2SO_4 solution	D_2O	D_2O	0.9×10^{14}	300°C.	Dec. 1957
—	90% UO_2 + H_3PO_4	H_2O	H_2O	1.8×10^{13} (maximum)	316°C.	1956
...MW ...1958)	2.8% enriched	Graphite	Na	4×10^{13}	516°C.	April, 1957
...5 MW	2.5% enriched	Graphite	Na	2×10^{13}	496°C.	1962
...0 MW	About 2% enriched	D_2O	Na	3×10^{12}	510°C.	1962
—	—	—	—	—	—	1956
—	U^{235} in Bi	Graphite	Bi	7×10^{13} (centre)	549°C.	1961
—	Highly enriched	Terphenyl	Terphenyl	5.44×10^{13}	276°C.-376°C.	1957
...4 MW	1.8% enriched	Terphenyl	Terphenyl	1.0×10^{13}	325°C.	1961(?)
...5 MW	Slightly enriched	D_2O	Gas	—	—	1963
...00 kW	U-Zr alloy 93.2% enriched	—	Eutectic NaK	0.8×10^{14}	316°C.	1951
...5 MW	49% enriched	—	Na	2.6×10^{13}	482°C.	1960
—	Molten Pu	—	NaK	—	—	1960
...W (1961) ...W (1962)	U-Mo alloy 27% enriched	—	Na	0.5×10^{14}	427°C.	1960

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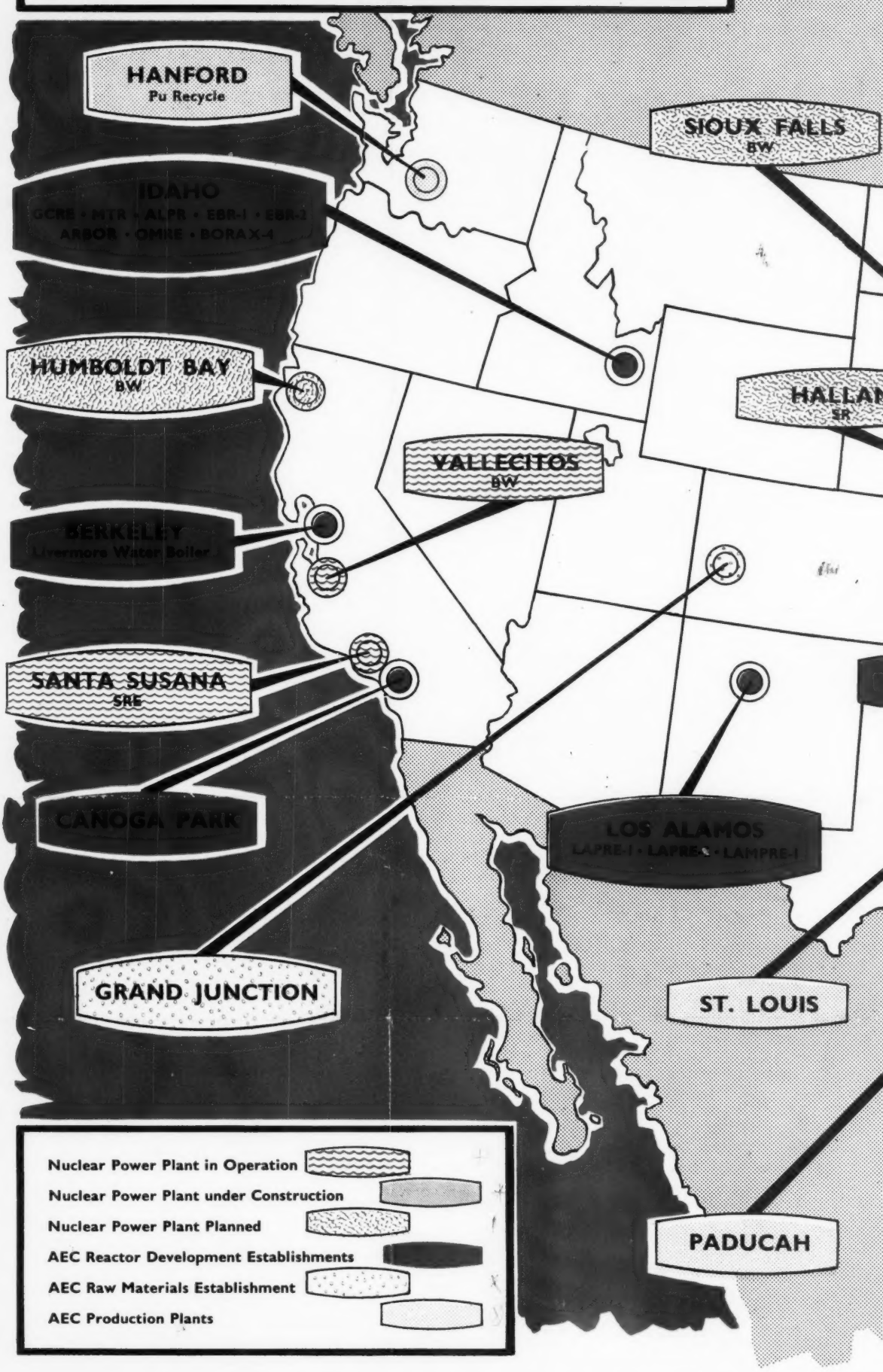

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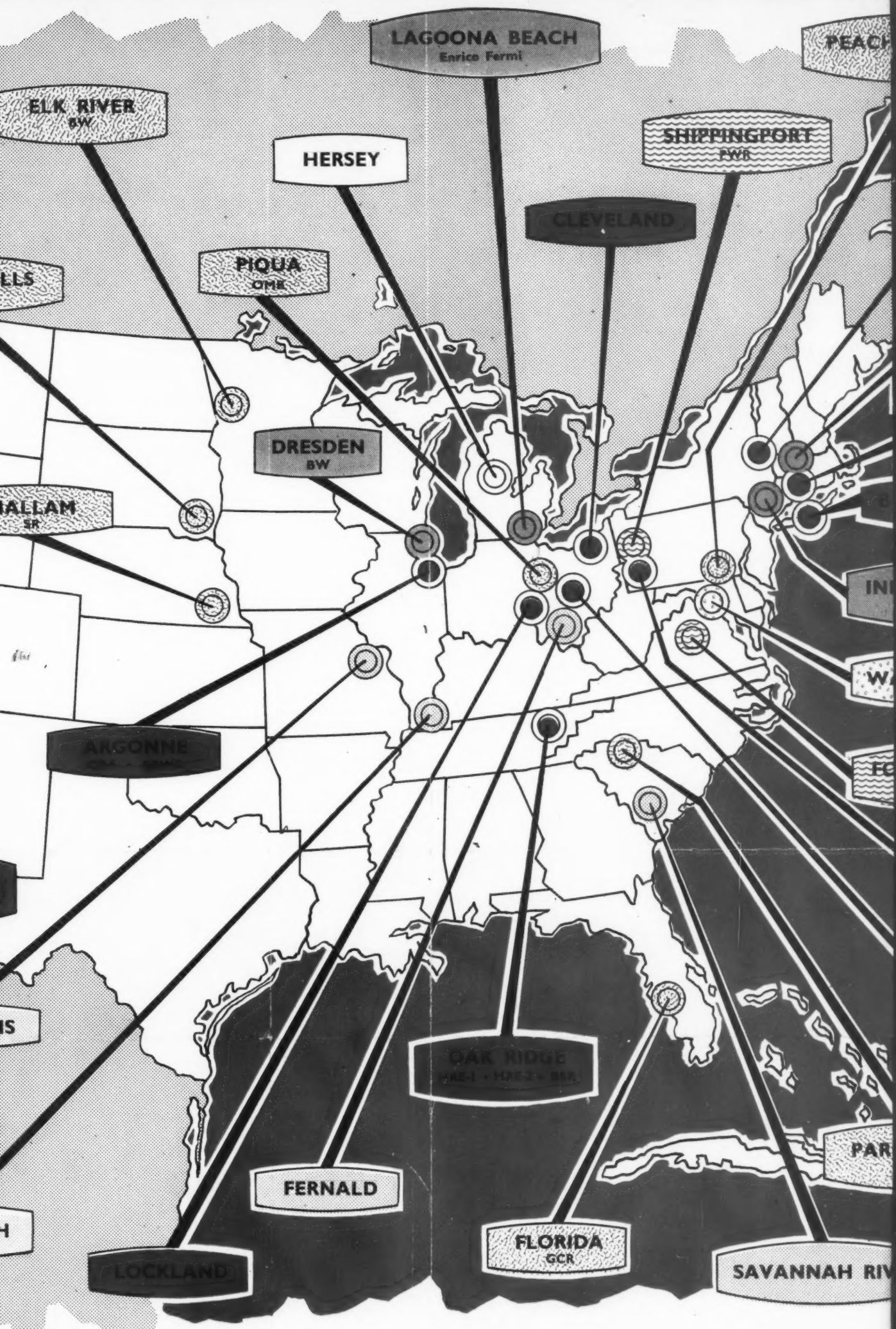

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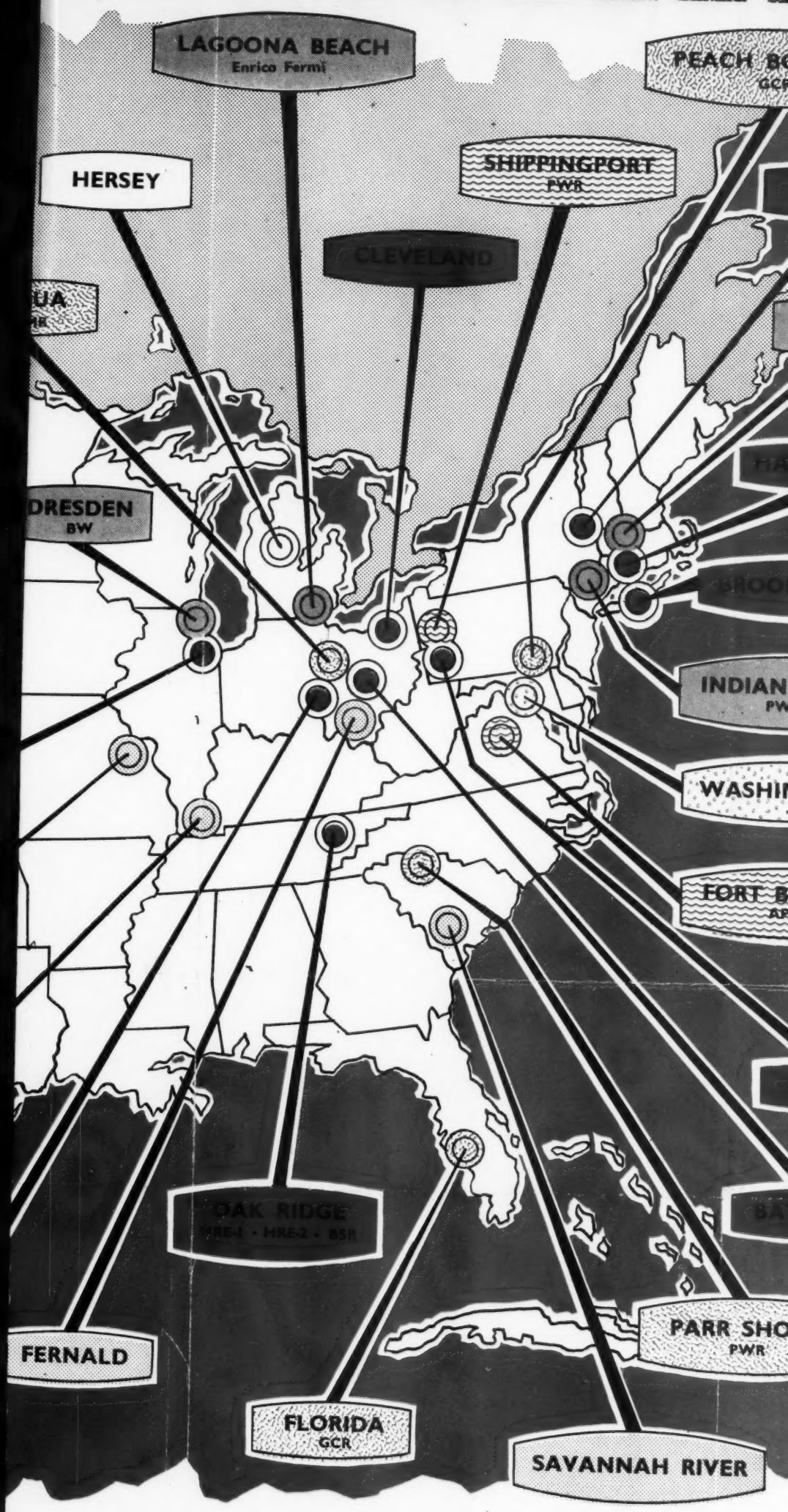
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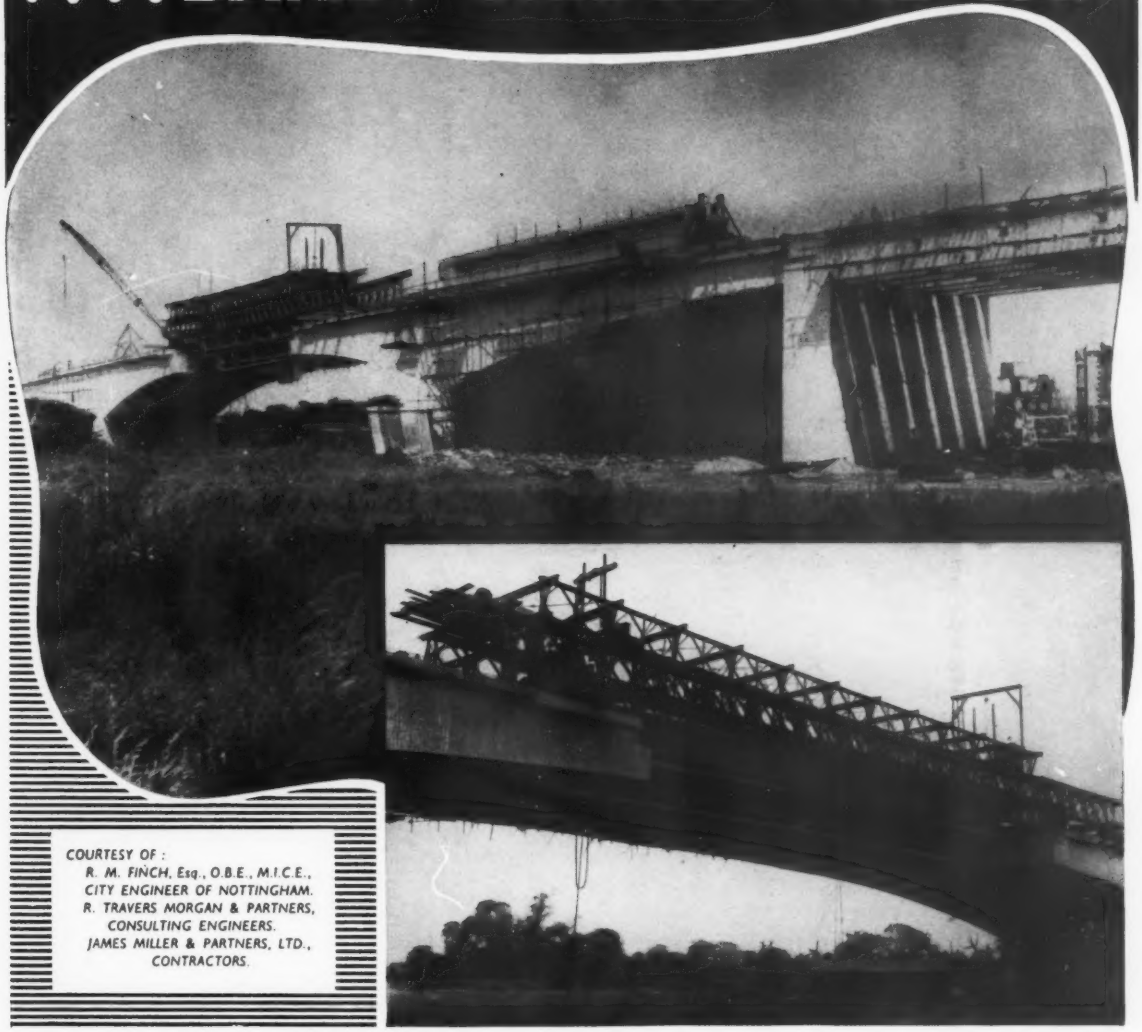
Nuclear Power Rocket Tests
(Edgerton, Germeshausen and Grier) **(149)**
(Reynolds Electrical and Engineering Co.)

N.B.—Figures in brackets are of the number of employees at December 31st, 1958.
**Includes employees engaged at Oak Ridge Laboratory.*
†Includes employees engaged by Brush Beryllium at Luckey.
‡Includes employees engaged by Brush Beryllium at Cleveland.
Details of principal research and power reactors are listed overleaf.

. . . . BAILEY BRIDGES THE GAP



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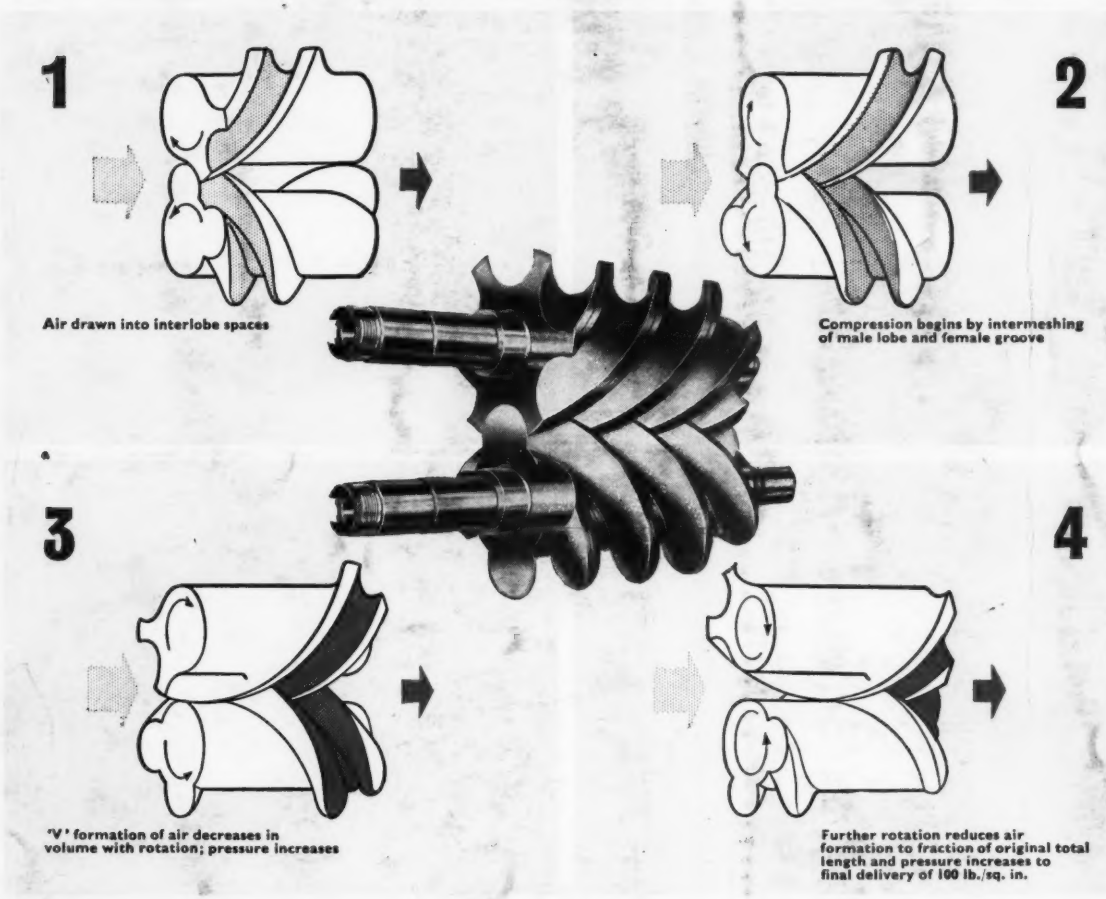
Portable air compression the Holman way


1
Air drawn into interlobe spaces
2
Compression begins by intermeshing of male lobe and female groove
3
'V' formation of air decreases in volume with rotation; pressure increases
4
Further rotation reduces air formation to fraction of original total length and pressure increases to final delivery of 100 lb./sq. in.

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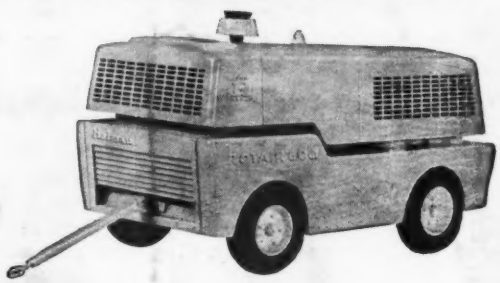

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